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An appraisal of nesting songbird habitat, Coyote creek, riparian station, 1997-98

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AN APPRAISAL OF NESTING SONGBIRD HABITAT, COYOTE CREEK RIPARIAN STATION, 1997-98

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ABSTRACT

AN APPRAISAL OF SONGBIRD NESTING HABITAT, COYOTE CREEK RIPARIAN STATION, 1997-98.

By Erin O'Bryan

This thesis assesses Salt Marsh Yellowthroat and Song Sparrow nesting response to restoration age, management strategies, vegetation structure, and species composition in restored upland riparian habitat and an overflow channel along Coyote Creek, a coastal urban creek, at Coyote Creek Riparian Station (CCRS), Milpitas, California from 1994 to 1998.

Population dynamics and nesting outcomes provided evidence that the nesting habitat in both restored and managed habitat at CCRS is functioning, as of 1998, as a sink to local population numbers. Mowing of the overflow channel in 1996 had an immediate negative effect on the nesting success of both birds. Restoration age, vegetative structure, and/or proximity to water contributed significantly to variability in nesting success.

It is recommended that native California Goldenrod be propagated at CCRS to out-compete Pepper Grass, a non-native, invasive plant, which harbored the highest proportion of failed nests for both bird species in 1998.

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I dedicate this thesis to the memory of my father, William S. O'Bryan, whose unfaltering love and moral support helped to me to maintain my enthusiasm for this work, especially during the data collection phase.

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Problem Statement

This thesis explores the role that vegetative characteristics of restored and managed habitat play in the reproductive success of Song Sparrows (*Melospiza melodia santaecrucis*) and Salt Marsh Yellowthroats (*Geothlypis trichas sinuosa*) in the South San Francisco Bay area. In particular, it assesses the current capacity of restored riparian habitat and a managed overflow channel to provide adequate nesting habitat for Salt Marsh Yellowthroats and Song Sparrows at Coyote Creek Riparian Station (CCRS) located in Milpitas, California, at the south end of the San Francisco Bay. Data were collected during the 1997 and 1998 breeding seasons. Shortly after data collection for this thesis ended in the fall of 1998, CCRS closed down and the management of the property shifted to the Santa Clara Valley Water District (SCVWD).

The four end-products of this thesis are: (1) an overview of the change in local *G. t. sinuosa* and *M. m. santaecrucis* breeding populations, from 1994-1998, in the 2 habitats at CCRS; (2) description of the vegetative profile in the 2 habitats; (3) the quantification of vegetative characteristics found to be important nesting habitat components for these species in the 2 habitats; and (4) an estimation of likely future reproductive output given the condition and management of the nesting habitat currently being used by these two species at CCRS. Data were collected during the 1997 and 1998 breeding seasons.

Importance

Region-wide, the rapid landscape alterations resulting from urban expansion have caused massive destruction of wildlife habitat in the San Francisco Bay area. In the last 100 years, over 80% of the original songbird habitat in the Bay Area has been lost due to filling and diking of marshes, stream channelization and conversion for agriculture, road building, and construction (Jensen et al., 1993). Historical changes in wetland habitat are described by Marshall and Dedrick (1994) who estimated that San Francisco Bay tidal marshes have been reduced to less than a sixth of their former extent from 78,410 ha, in the 1850's, to 11,870 ha.

As of 2001, the land surrounding CCRS and the restoration site is undergoing conversion from agricultural to urban land uses. From the 1940's until the early 1980's, fruit growers intensively used the riparian floodplain in which CCRS is located. Evidence of former land use, a remnant pear tree orchard, was removed to make way for the pilot restoration project at CCRS in 1982 (Jaramillo, et al., 1996). The large scale housing developments and business parks now being built in Milpitas are manifestations of the fast pace of urban growth currently taking place in the cities of the South San Francisco Bay region. The creek and adjacent urban land uses will continue to have a strong effect on the state of CCRS habitat over the long term.

In addition to the removal of a vast proportion of the native landscape, the degradation of the remaining habitat may cause further declines among native songbird populations in the Bay Area. Ornithologists suspect that resident species of San Francisco Bay marshland and associated riparian zones, such as Salt Marsh Yellowthroats and Song Sparrows have been adversely affected by these large alterations of their native habitat (Marshall and Dedrick, 1994; Hobson, et al., 1985; Foster, 1977). Salt Marsh Yellowthroat numbers, in particular, are suspected to be severely depressed from historic levels, from the 1950's to present (Hobson, et al., 1985; Foster, 1977; Marshall and Dedrick, 1994).

The Salt Marsh Yellowthroat is a species of special concern in California. Understanding the habitat requirements needed to support successful nesting of this species is critical for the species to survive in the San Francisco Bay area. In particular, due to the small size of the entire population of *G. t. sinuosa* and the patchy nature of their current habitat, it is very important to determine what types of habitat it prefers for breeding and to develop management strategies accordingly.

By contrast, the population of *M. m. santaecrucis* at CCRS is a common endemic race of Song Sparrow which occupies upland habitat in the East Bay and San Francisco Peninsula hills (Marshall and Dedrick, 1994). The decision to evaluate the reproductive success of *M. m. santaecrucis* in addition to *G. t. sinuosa* is supported by Martin (1989) who convincingly argues that it is important to document the value of the habitat for both special status species and cohabitants, because all populations may exhibit change in response to habitat growth and alteration. Martin describes two important requirements for effective wildlife management practices: (1) identification of specific habitat features and associated resources that directly influence reproduction or survival of a special status species and (2) simultaneous consideration of the consequences of those features for coexisting species. Also, although *M. m. santaecrucis* populations in the Bay Area may not be as susceptible to environmental degradation as are Salt Marsh Yellowthroats, the evaluation of nesting habitat for the Song Sparrow at CCRS may provide important insight into likely population responses of closely related sensitive races of Song Sparrows, such as *M. m. pusillula*.

It is especially important to document any correlation between population change and habitat alteration in order to successfully manage and create additional habitat. Habitat restoration is one of several common forms of mitigation presently required by environmental laws, such as the National Environmental Policy Act (NEPA), to compensate for environmental impacts caused by building, paving, dredging, and filling activity in the Bay Area. In 1987 the Santa Clara Valley Water District (SCVWD) initiated the restoration of 13.1 ha of riparian forest in the upland riparian zone of Coyote Creek as mitigation for proposed flood control impacts from the Lower Coyote Creek Flood Control Project (Jaramillo, et al., 1996). The assessment of Salt Marsh Yellowthroat and Song Sparrow reproductive success given by this thesis research will provide useful information to SCVWD for enhancing existing restored habitat or creating more songbird-nesting habitat at or near CCRS.

Restoration projects must be monitored in order to ensure that they: (1) function on an ecosystem level; (2) contribute to a regional biodiversity that represents historic conditions as closely as feasible; (3) preserve any keystone species that might occupy the restored habitat; and (4) function as they were designed (i.e. meet performance criteria set for the project). As they grow both in number and acreage, mitigation restorations play an increasingly important role in the preservation of existing species and the future biodiversity of native San Francisco Bay area landscapes.

Restorations are not necessarily designed to include spatial arrangements of plants, dead branches, ground cover, leaf litter, or other key vegetative characteristics that animals depend upon for their survival. When specific vegetative habitat elements that provide cover from predators, nest parasites, and more extreme weather, ample food, and preferred nesting substrate are under-represented in a restored habitat, the restoration may fail to preserve a species or species. The restored habitat at CCRS must be carefully monitored to ensure that adequate nesting and foraging habitat conditions are provided and maintained.

Generality

From a policy standpoint, previous attempts to protect bird populations that are dependent upon shrinking parcels of native habitat have often been inadequate. The Willow Flycatcher (*Empidonax traillii*) and the California Gnatcatcher (*Polioptila caerulea*) are two songbirds that are currently facing extinction in California due to extensive destruction of their native habitat. The manner in which these two species became federally listed as threatened species under the Endangered Species Act of 1973 (ESA) illustrates how political complications greatly impede the process of species protection. Prior to being Federally listed as threatened, the statewide populations of these two species progressively declined while conservationists, public agencies, and private landowners quarreled over the validity of the two birds' official legal status. According to Hobson, et al. (1985), the Salt Marsh Yellowthroat similarly became a topic of contention when it was nominated to be listed as a California endangered species. The California Winter drought of 1975 to 1976 had devastating effects on local *G. t. sinuosa* populations, prompting the original petition in 1976. However, the petition for listing was denied because the species' population decline had tapered. This bird is now a state species of special concern (California Dept. of Fish and Game, 1997).

Aside from the documented population decline in the late 1970's, the long-term consequences of habitat loss for Salt Marsh Yellowthroats have not been fully quantified. Such consequences may be severe. Habitat loss can make at-risk species particularly vulnerable to intermittent anthropogenic or natural stresses. If the habitat that has already been lost is not restored, there will be no buffer for recovery of these species if they are stressed further by drought, climate change, air and water pollution stresses on habitat, or any combination of these environmental stresses that appear to be growing more common and widespread with time.

While preserving the remaining habitat for a rare species is critical, a concerted effort is needed among agency wildlife biologists, restoration ecologists, and regional planners to restore and enhance viable habitat for at-risk species that are not currently protected by the ESA or other domestic wildlife conservation policies. It is necessary that restorationists include specific habitat requirements within the design of restored native habitat in order to improve at-risk species' chances for survival. Ideally, restorations should renew as many key habitat characteristics as possible for local wildlife, regardless of their official legal status under the ESA. To do that, we must understand what these key habitat requirements are. This thesis quantifies several nesting habitat characteristics for Salt Marsh Yellowthroats in the South San Francisco Bay and links them to Salt Marsh Yellowthroat population dynamics.

At CCRS the avifauna were studied as part of a wildlife monitoring program to gauge the success of the SCVWD's restoration mitigation. The characterization of Salt Marsh Yellowthroat nesting habitat at this site serves as a supplement to existing annual wildlife monitoring program efforts, by providing detailed information on the current breeding status of Salt Marsh Yellowthroats. San Francisco Bay Area wildlife biologists, restoration ecologists, and ornithologists from the Department of Fish and Game (DFG), the Santa Clara Valley Water District (SCVWD), and the Santa Clara Chapter of the Audubon Society may find information in this thesis useful to designing additional projects that will enhance or restore Salt Marsh Yellowthroat nesting habitat. It is hoped that significant habitat preservation and restoration efforts could avert the need to list the Salt Marsh Yellowthroat in the future.

Focus

The major objective of this work is to determine whether the CCRS restoration successfully supports breeding populations of Salt Marsh Yellowthroats and Song Sparrows. Because CCRS contains several areas with clearly distinct habitat characteristics and management approaches, this work also examines differences between these areas in breeding success, probable causes for those differences, and the effect of current management practices on breeding success. The three main foci of the research are:

Focus 1. Population Dynamics: Have resident populations of *G. t. sinuosa* and *M. m. santaecrucis* changed significantly over 5 years of observation at CCRS overall.? If so, why?

Focus 2. Nesting outcomes: What nest factors are correlated with nesting success?

Focus 3. How are population dynamics and nesting outcomes specifically related to each of the three habitat patch types ("Old Reveg.", Overflow Channel", or New Reveg.")?

Each of the three questions has been broken down into specific answerable research objectives. These objectives are addressed in the form of an in-depth investigation of reproductive success and nesting habitat of these bird species at CCRS. Three different habitat patch types are evaluated: a pilot revegetation site which covers 1.7 ha ("Old Reveg."); an overflow channel in the upland riparian zone, that was created and is managed for flood control which covers approximately 3.6 ha ("Overflow Channel"), and the newest restoration site established in the fall of 1993 which covers an area of 3.2 ha a ("New Reveg.").

Because the three patch types at CCRS have distinct habitat characteristics and management approaches, this work examines differences and/or changes in breeding success rates, probable causes for those differences, and the effect of current management practices on breeding success among each of the three patch types.

Nesting Stresses

Specifically of concern here is the possibility that the physical and biotic landscape profile resulting from human manipulations of native plant growth may not provide adequate cover from predators or substrate for nesting songbirds in the restored habitat at CCRS. Moreover, mowing an overflow channel that bisects the restored habitat, may substantially disturb these birds during the nesting season. Mowing may displace animals that inhabit vegetation growing in these channels in the intervals between mowing. Furthermore, mowing the overflow channel may increase edge-zone and entryways for nest predators and brood parasites, deplete preferred nest plants, and deplete preferred nesting microhabitat for both species. Also, birds that typically inhabit marshes may be more inclined to build nests in the structurally similar overflow channel rather than the upland riparian zone.

If the timing of mowing coincides with the nesting season, marsh-loving bird nests existing in the overflow channel would be destroyed. The periodic flooding of the over flow channel may further complicate matters by altering both timing of nest building and the duration of the nesting season. If, for example, flooding occurs at the beginning of the nesting season while birds are attempting to pair bond, the time allotted for breeding and nest building will be truncated and the timing of nesting may occur later in the season. If nest building occurs too far into the summer months, seasonal die back of tall herbaceous plants will restrict the number of nests that can be built as desirable nest cover and nest building material grow scarce.

Brood parasitism may also contribute to nesting stress. This phenomenon occurs when a parasitic bird species, such as the Brown-headed Cowbird, lays one or more of its own eggs in a nest, leaving the host bird to do all of the feeding and rearing of the Cowbird young in addition to its own brood. Host species nestlings inevitably suffer and often die because of brood parasitism. It is not known whether San Francisco Bay endemic Song Sparrows or Salt Marsh Yellowthroat are experiencing any immunity to particular nesting stresses, such as brood parasitism, because nest failure incidence and causes have not been well documented for these local populations. Moreover, despite the fact that these factors are not all directly human-generated, the indirect influence of human landscape alterations on these "natural" nesting stresses cannot be ignored. In riparian habitat near urban areas, the order of importance of nesting stresses may change according to the extent and variation of suitable habitat for predators and parasitic Cowbirds at the site and on adjacent lands. Furthermore, extensive habitat loss and increased habitat fragmentation have occurred for both species over the last 100 years, thereby improving odds that both parasitism and predation pressure are increased from the original condition. The degree to which human alteration of songbird habitat at CCRS further exacerbates these nesting stresses must be understood in order to improve current nesting conditions, if such improvement is necessary.

Objectives

The following objectives delineate specific strategies designed to address the relative importance of the main nesting stresses described in the focus for Salt Marsh Yellowthroats and Song Sparrows at CCRS with as much accuracy as possible given the time constraints of the study (2 breeding seasons of observation).

Focus 1. Population Dynamics: Have resident populations of *G. t. sinuosa* and *M. m. santaecrucis* changed significantly over 5 years of observation at CCRS overall.? If so, why?

- Objective 1.1 What are the documented population dynamics changes for Salt Marsh Yellowthroats and Song Sparrow populations at CCRS from 1994 to 1998?
- Objective1.2 What is the nesting success (N_S) for Salt Marsh Yellowthroat and Song Sparrow populations at CCRS, as a whole and by patch type ("Old Reveg.", Overflow Channel", or New Reveg.")?
- Objective 1.3 How might changes in local Salt Marsh Yellowthroat and Song Sparrow population dynamics from 1994 to 1998 be influenced by nesting success?
- Objective 1.4 Are the populations of Salt Marsh Yellowthroats and Song Sparrow populations at replacement at CCRS?

Focus 2. Nesting outcomes: What nest factors are correlated with nesting success?

- Objective 2.1 Do nest densities correspond to nest success/non-success for each patch, Mayfield nesting success, or reproductive index values?
- Objective 2.2 Based on nest search data how are nesting Salt Marsh Yellowthroat and Song Sparrow populations at CCRS being affected by nest parasitism and predation, as a whole and by patch type?

Focus 3. How are population dynamics and nesting outcomes specifically related to each of the three habitat patch types ("Old Reveg.", Overflow Channel", or New Reveg.")?

- Objective 3.1 What average structural vegetative characteristics, leading nest plant cover and nest plant substrates are present within each of the three patch types at CCRS?
- Objective 3.2 Does nest success/failure correlate with the specific vegetation growing within a patch type?
- Objective 3.3 Are Salt Marsh Yellowthroat and Song Sparrow populations at CCRS positively or negatively correlated with restored habitat management strategies as a whole or by patch type?
- Objective 3.4 Are the extent and timing of overflow channel mowing and debris control correlated with reproduction of the two species?

Related Research

Historical Assessments of Habitat and Population Status in the San Francisco Bay Area

From the time that Grinnel first documented the characteristics and behavior of the Salt Marsh Yellowthroat, in the 1850's, to 1976 no formal estimate of Salt Marsh Yellowthroat numbers was ever completed. The assertion has been made, however, that Salt Marsh Yellowthroat numbers must have declined from numbers in Grinnel's time due to the extensive degradation of Salt Marsh Yellowthroat habitat (Hobson, et al., 1985; Marshall and Dedrick, 1994). By the early 1970's it was estimated that 75% of the original habitat of Bay Area song birds had been lost, due principally to landfilling and diking of Bay Area marshland. In 1973, Richard Mewaldt, former director of the Coyote Creek Riparian Station (CCRS) and Howard Shellhammer, a professor at San Jose State University, proposed that the Salt Marsh Yellowthroat be evaluated for protection under the Endangered Species Act (Foster, 1977). With that petition and funding from Federal Aid in Wildlife Restoration, Margaret Foster (1977) began a three-year survey in 1975 to determine the distribution and abundance of Salt Marsh Yellowthroats throughout its range and to evaluate the quality and extent of Yellowthroat habitat. From this survey, it was concluded that the numbers of breeding Yellowthroats, at 165 breeding pairs observed between 1975 and 1976, had drastically declined from previous levels. In her report, Foster (1977) recommended giving endangered species status to the Salt Marsh Yellowthroat. However, 1975 and 1976 were severe drought years with significant impact on marsh vegetation, and it was recognized that the Yellowthroat status reported in that study might not be representative of "normal" conditions. Therefore, the petition to list the bird as endangered was unanimously rejected by California Department of Fish & Game officials (Foster, 1977).

In 1975, the status of five Bay Area Song Sparrow subspecies was also documented. Mewaldt and Shellhammer submitted a petition to list one subspecies, *Melospiza melodia samuelis*, as a threatened species in 1976. Habitat loss and drought both could have played an important role in the Song Sparrow and Yellowthroat population decline at the time of these surveys.

The urban assault on local songbirds habitat has continued. A decade later, Hobson, et al. (1985) estimated that up to 90% of potential habitat for Salt Marsh Yellowthroats had been destroyed due to urbanization since the early 1900's. In 1986, Gregory claimed that fresh water from sewage treatment was eliminating salt marsh plants from the south end of the San Francisco Bay, jeopardizing the Alameda Song Sparrow (Marshall and Dedrick, 1994).

In 1994, Marshall and Dedrick surveyed for *G. t. sinuosa* and three field-identifiable subspecies of the Song Sparrow still known to occupy remnants of the original 78,398.9 ha of tidal marsh vegetation in the San Francisco estuary. Their 1994 survey determined that the habitat for these four birds had been reduced by 85% to 11,862.1 ha. In addition, they found that species numbers are currently at 15% of those in the 1850's due to obstruction of tidal flow by urban development. Local ornithologists strongly suspect that these populations continue to suffer from factors associated with diminished habitat as Bay Area marshes and riparian zones become increasingly urbanized (Jaramillo and Otahal, pers. comm.). The Point Reyes Bird Observatory (PRBO) initiated a recent assessment of these tidal salt marsh species in 1995 with funding provided by the National Biological Service. The survey continued until 1998, providing updated information about the current population status and trends for these species. This updated information has not yet been published.

Life Histories and Bay area Distribution

The Salt Marsh Yellowthroat (*Geothlypis trichas sinuosa*) is a small (avg. male wingspan =50-55mm.) yellow and black songbird. It is a year-round resident and is considered a localized "sedentary taxon" (Grinnell, 1901) because it does not tend to migrate far, if at all, from the San Francisco Bay area. It has been generally understood that Salt Marsh Yellowthroats usually nest in salt and freshwater marsh habitat, only nesting in upland habitat on rare occasions (Otahal, pers. comm.). Very little is known about the local movements of the birds between seasons. CCRS ornithologists have surmised that small communities of Salt Marsh Yellowthroats remain in the same general area, moving to surrounding areas for temporary periods especially over the winter, and then return to their breeding grounds only a short distance away the following spring (Jaramillo and Otahal, pers. comm.).

Marshall and Dedrick (1994) described the breeding range of the Salt Marsh Yellowthroat as undefined. The location and numbers of breeding pairs were quantified, however, by Hobson, et al. (1985) who reported 165 breeding pairs of *G.t. sinuosa* located at the time of the 1977 survey compared to 569 breeding pairs located during the 1985 survey conducted in the same area. Although they reflect an increase from the critically low numbers during the drought years of the 1970's, the 1985 numbers are still low compared numbers of other songbird species that inhabited Bay Area riparian zones and marshlands.

Marshall and Dedrick (1994) studied the Alameda Song Sparrow (*M. m. pusillula*), Samuel's Song Sparrow (*M. m. samuelis*), and the Suisun Song Sparrow (*M. m. maxillaris*). These species are found almost exclusively in tidal salt marsh habitat of the San Francisco Bay. These authors found that a more common species of Song Sparrow (*M. m. santaecrucis*) occupies the area of CCRS. Downstream from CCRS, the Alameda Song Sparrow (*M. m. pusillula*), a small endemic population, occupies tidal salt marsh near the mouth of Coyote Creek at Triangle Marsh (Marshall and Dedrick, 1994). Although they expressed concern that the larger population of *M. m. santaecrucis* may hybridize the Alameda Song Sparrow out of existence, Marshall and Dedrick (1994) found that for unknown reasons, as of 1994, *M. m. santaecrucis* had not yet invaded fresh-water habitats along the shore of the south bay. They explain that intergradation between Bay Area Song Sparrows of the salt marshes with those of the uplands, had caused dilution of racial traits of endemic Song Sparrows in the marshes of Marin and Contra Costa Counties. Careful study of the life histories and reproductive success rates of both *M. m. santaecrucis* and *M. m. pusillula* is critically important to understanding whether additional habitat alteration may be facilitating hybridization among these two species at the mouth of Coyote Creek.

For the Song Sparrow, the breeding season begins early as males begin to sing and establish territories in early to mid-March. Yellowthroat males start to sing in late

March. Territory establishment for both species continues for approximately 2-4 weeks, while pair-bonding between males and females is taking place. Females of both species begin nest building as soon as mating has occurred. The open cup nests of these two songbirds can be found side by side in Coyote Bush scrub and marshland habitat on the property. Once the nest is completed, females begin to lay eggs (3-4 for Yellowthroats and 3-5 for Song Sparrows) within 2 to 7 days. Eggs are incubated for 12 days for the Salt Marsh Yellowthroat, and 12-13 days for the Song Sparrow. The altricial hatchlings are fed until well after fledging, which occurs within 8-9 days after hatching for Yellowthroats and within 10 days for Song Sparrows (Bent, 1953; 1996).

Naturally Occurring Nest Mortality Factors

While human-generated landscape alterations seriously affect the survivorship of song birds at CCRS, also the unique relationships between these and other species of birds, mammals, and reptiles always have a strong bearing upon their overall reproductive success and survival. In particular, the importance of nest predation and parasitism are noted in the literature. Best and Stauffer (1980) rank the causes of nest failure for North American passerines in order of importance, as: 1) predation by birds, snakes, or small mammals; 2) predation by large mammals; 3) nest desertion; 4) cowbird parasitism; and 5) natural disasters. Based on a comprehensive review of nesting success and sources of stress for 32 species of passerines that migrate to the Neotropics, Martin (1989) also found that nest predation was the primary cause of mortality for all but a few species of birds. Marshall and Dedrick (1994) assert that Norway rats, red foxes, and house cats could be potential leading predators for these songbirds in the Bay Area.

Brood Parasitism

Martin also found that brood parasitism is a major cause of nest stress in North America. Brown-headed Cowbirds (*Molothrus ater*) and other brood parasites lay their eggs in the nest of a host species, leaving the feeding and care of altricial Cowbird young to the host species. The often larger Cowbird young will beg for more food than the host young will. Host parents then spend a disproportionate amount of energy to sustain the Cowbird chick. Nest parasitism, therefore, frequently results in host nestling fatality due to starvation and is a leading cause of nest mortality for many species. In Martin's study, the Common Yellowthroat (*Geothlypis trichas*) was one of the species for which nest parasitism by Brown-headed Cowbirds (*Molothrus ater*) outweighed predation as the leading cause of nest mortality. This may or may not be the case in California. According to Spautz (pers. comm.), neither the Kern River nor the statewide populations of Common Yellowthroats appear to be experiencing substantial Brown-headed Cowbird parasitism. In addition, the noted decline of Song Sparrow populations is apparently not attributable to Brown-headed Cowbird parasitism, at least in those habitats that have not been fragmented (Arcese, et al., 1996; Smith and Arcese, 1994).

Density Dependent Mortality and Nesting Behavior

Because the patches of available nesting habitat at CCRS are limited and nest concentrations within these patches appear to be relatively high, it is possible that these species will exhibit density-dependent behavioral responses under extended observation.

Such behavioral responses may affect the overall nesting success of these species at CCRS. For example, Brown-headed Cowbird hosts sometimes exhibit behavioral responses that may counter nest mortality associated with the additional energy required to maintain the Cowbird chick (Spautz, 1997). Such responses include: burial of the Cowbird egg at the bottom of the nest or the removal of the egg from the nest.

Island Biogeography Theory and the Isolation of Resident Wildlife Populations

Marshall and Dedrick's concern that marshland degradation has caused these and other wildlife populations inhabiting Bay Area wetland and riparian zones to become increasingly isolated remains wide-spread, today (Jaramillo and Otahal, pers. comm.). The destruction of available marsh and riparian habitat occurring in the Bay Area have created many islands of increasingly isolated habitat, with longer distances between, located in a hostile sea of urban sprawl. Even for mobile species such as birds, species abundance may decline due to the increased difficulty for birds to move between "islands" of habitat as the distance between habitat fragments increases (MacArthur and Wilson, 1967). This problem worsens with time and as habitat patches diminish in size (Jensen, et al., 1993). In general, mortality rates rise as distance between viable habitat increases and protective cover from natural predators decreases (Freemark and Collins, 1989). The islands of remaining marsh and riparian habitat that Bay Area Yellowthroats and Song Sparrows are now forced to inhabit may provide very little protective cover from natural predators and few areas where these species can successfully nest without being plagued by nest parasites such as cowbirds or predators such as foxes, cats, or scrub jays. Freemark and Collins (1989) documented a reduction in the nesting success rates for both Song Sparrows and Common Yellowthroats because of increased nest mortality associated with riparian forest fragmentation in the eastern United States. In addition to increased predation and parasitism, isolated populations become more susceptible as a whole to disease or genetic mutations as their genes become more similar with inbreeding (Furness and Greenwood, 1993). These hereditary impacts may now occur in the many small pockets of Salt Marsh Yellowthroat and endemic Song Sparrow populations.

Ecotones, Density-dependent Mortality, and Population Sinks and Sources

Increases in nest density and mortality have been strongly associated with ecotones or habitat discontinuity. Gates and Gysel (1978) describe the phenomenon as a tendency for individuals of bird and other species to aggregate at the border between different plant communities, such as fields and forests. Both high species richness and high nest densities for individual species have been associated with ecotones (Best and Stauffer, 1980). The avian research coordinator at CCRS, Chris Otahal, has described the habitat there as "all ecotone", because habitat discontinuities are common while expansive areas of contiguous habitat exist in only a few locations within the site. When Salt Marsh Yellowthroats and Song Sparrows cluster their nests near the ecotone, increased gaps and openings allow for increased vulnerability of these nests to predators (Best and Stauffer, 1980). Moreover, ecotones can function as a trap by concentrating nests and thereby increasing density-dependent mortality. Predation and Cowbird parasitism are considered density-dependent mortality factors because these phenomena increase with higher prey or host population densities.

Temple and Cary (1988) classify habitat in urban areas as "sinks", or locations of *negative* songbird productivity, while more expansive areas of natural habitat are considered "sources" for recruitment of songbirds into the impacted areas. Even in a relatively large parcel of isolated habitat, very high density-dependent mortality can reduce the population faster than it can reproduce itself. Such a parcel becomes an ecological trap as the attractiveness (relative to the surrounding developed landscape) of the ecotone and/or the relatively higher quality of the habitat continually attracts immigrants into the area. The remaining habitat fragments of the South San Francisco Bay may be functioning as ecological traps for source bird populations that disperse from expansive habitat in the North Bay into the area. Similarly, the mowed area of the overflow-channel might be functioning as a sink to the surrounding, more stable, habitat.

Almost all of the topics described above could have a direct bearing on the outcome of nesting success or failure and population dynamics of Salt Marsh Yellowthroat and Song Sparrows documented by this thesis. Although drought has not been a factor during the 1997 and 1998 breeding seasons at CCRS, habitat loss due to urbanization continues unabated in the municipalities of Milpitas and the South San Francisco Bay area. Additionally, sewage treatment plant outflow continues to have an effect on the salinity of the South Bay and, therefore, the limited existing salt marsh habitat continues to be depleted. The remaining fragments of salt marsh and riparian habitat in the South San Francisco Bay continue to be isolated, and the sedentary nature of the Salt Marsh Yellowthroat limits possibilities for genetic influx into the local population. Although these issues can only be addressed preliminarily in two breeding seasons of study, each of these factors may have an impact on the outcomes of this thesis. Such factors would be reflected by unusually high (when compared to the literature) nest densities; unusually high rates of nest abandonment, predation and/or parasitism; unusually high rates of easily observable congenital birth defects or avian diseases among the chicks or adult birds of either species; or an unusually high disparity between the numbers of adult birds which return to CCRS annually, and the number of young produced on-site, annually.

Methods

Study Site

Coyote Creek Riparian Station

The Santa Clara Valley Water District developed the restoration of Coyote Creek as mitigation for a City of San Jose flood control project. Two restoration sites, initiated at separate times over the past ten years, are located up to six kilometers from the mouth of the creek, where the creek empties into Artesian and Mud sloughs and then into the San Francisco Bay. In total, 13.1 ha of previously agricultural cropland are being replanted with riparian vegetation to compensate for the 4.9 ha of intact riparian vegetation removed by the construction of the Lower Coyote Creek flood control project.

In the edge-zone and patches where restoration does not include a dominant overstory, poison hemlock (*Conium maculatum*), non-native grasses and exotic forbs (*Lepidium latifolia*) are dominant plant species. Such areas are considered prime nesting and foraging locations for Salt Marsh Yellowthroats in the area (Otahal and Jaramillo, pers. comm.). Yellowthroats also utilize low-growing coyote bush (*Baccharus pilularis*) and mugwort (*Artemesia douglasii*) as nest plants in the drier scrub community located on the western side of the overflow channel, which divides the two revegetated sites. Additional plant species that dominate the scrub community are sage (*Artemesia* spp.), mulefat (*Baccharus* spp.), blackberry (*Rubus ursinus*), elderberry (*Sambucus mexicana*) and other shrubs (see Appendix A for plant species list).

Three microsites at CCRS were selected for study because of their potential to function as nesting sites for both species (see Figure 1). The characteristics of the three sites are as follows. **"Old Reveg."** is a pilot revegetation site planted in 1987, covering 1.7 ha and dominated by cottonwoods and willow trees. This was the initial attempt to restore habitat to the area. The site was planted at a time when less information on wildlife habitat restoration was available. This site differs from the other two patches in that it has lacked a definitive understory for the past eight years. An understory has begun to grow at "Old Reveg." but remains much less dense when compared to the understory of the two other sites (Otahal, pers. comm.).

"Overflow Channel", a maintained overflow channel, was created in 1989. The surface of the channel was lowered to a level of three feet NGVD (National Geodetic Vertical Datum). The majority of the earth moving was completed by May, 1990. The area sampled for this thesis is approximately 450 meters long and 80 meters wide (3.6 ha). Because the key function of overflow channels is to prevent flooding , it is important to maintain them free of vegetation and debris. The vegetation is mowed once every 2 to 5 years, between rainy seasons, to avoid obstructing the flow of water through the channel during flooding. This treatment is particularly necessary prior to winter and early spring, when the possibility of flooding is eminent. During the winter of 1996, the overflow channel was mowed for the first time in its 7 years of existence.

No vegetation was actively planted in the overflow channel, but vegetation grows there as a result of natural recruitment. Vegetation in the overflow channel was sparse and less than 1 ft. in height when the pilot study began in March of 1997, 5 months after mowing. The ground layer was composed of regrowing remnants of previously dominant Coyote Brush, along with an unidentified grass species and prickly ox-tongue (*Picris* *echioides*). By the end of the first breeding season, the vegetation had grown to 2-4 ft. in height and was dominated by thistle (*Carduus* spp.), wild radish (*Raphanus sativus*), and wild mustard (*Brassica kaber*).

The overflow channel currently provides valuable resources for songbirds at CCRS as a foraging area and a source of nesting material. During my initial pilot study in the 1997 breeding season, the area was often used as foraging grounds for female Yellowthroats, which were frequently observed flying into and out of the area from their nests. Although during the pilot study I observed only one singing Salt Marsh Yellowthroat male, and no other nesting behavior in the overflow channel, the channel may become a more viable source of nesting habitat as vegetation continues to grow. Yellowthroats were suspected to nest in the existing brush and herbaceous vegetation prior to construction of the overflow channel in 1991, and in the interim between that time and 1996, when it was mowed for the first time (Spautz, Otahal, and Jaramillo, pers. comm.). Hildie Spautz, a biologist at the Kern River Research Center (KRRC), conducted a survey of Salt Marsh Yellowthroats nests at CCRS in 1994. She asserts that the vast majority of Yellowthroat nests that she encountered during the 1994 breeding season were located in the vegetated overflow channel (pers. comm., 1996).

"New Reveg.", refers to a newer revegetation site that was planted in Fall of 1993. This microsite covers an area of 3.2 ha and is composed of 20% trees, 60% shrubs, and 15% herbs. Twenty-five different plant species were planted in the area, in 1993. In 2001, however, the plant community was dominated by willows (*Salix* spp.), cottonwoods (*Populus fremontii*) , oaks (*Quercus kellogii, Q. agrifolia, Q. lobata*), rose (*Rosa californica*), and California blackberry (*Rubus ursinus*).

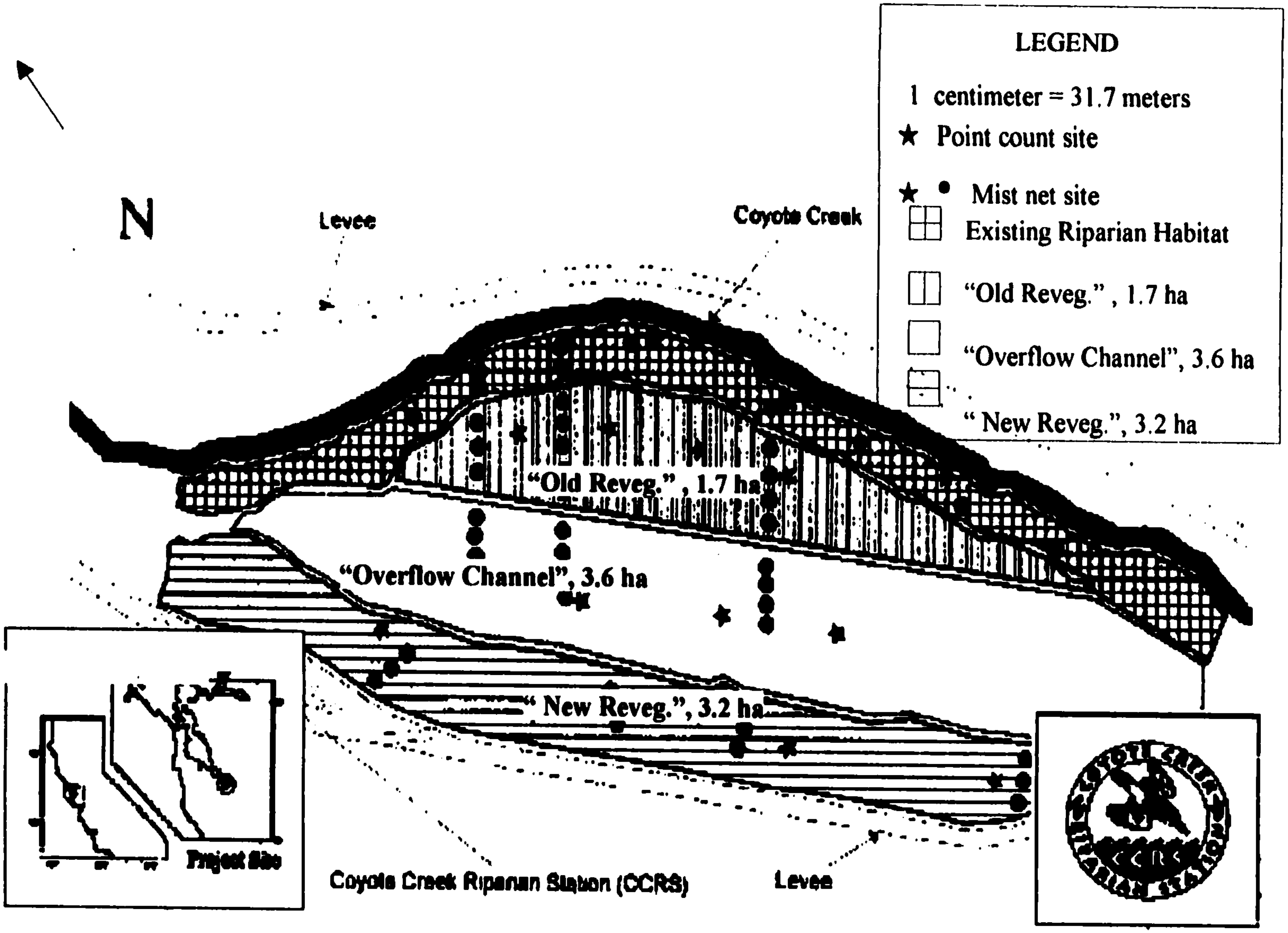

Figure 1. Study sites at CCRS.

Study Design

Pilot study data on the habitat characteristics and use by nesting Salt Marsh Yellowthroats and Song Sparrows were collected at CCRS during the 1997 breeding season. The data collected during the pilot study was used initially to verify that the birds actually nested at CCRS and that their nesting behavior and nest locations could be identified and properly documented. This data was later used for comparison with the data collected in 1998 because the data collection methods were standardized and the areas of each of the three distinct patch types remained the same for each year that samples were collected.

Formal data collection began on March 1^{st} and ended on July 15^{th} of 1998. The field season for both years was broken into three overlapping periods of data collection beginning with territorial mapping, conducted at the beginning of the nesting season. Territorial mapping was followed by nest searches, which continued until all nesting behavior had ceased. Vegetative assessment of the habitat, in a 50 meter radius surrounding each nest, was ongoing throughout the season.

The objectives were addressed through mist-net capture/recapture data, territorial mapping, an extensive nest search and a nesting habitat assessment at CCRS. Each of the three distinct patch types were sampled once per year, for 18 weeks in 1997 and 1998 using each of the four data collection methods. Correlations among habitat and nest success provided information to assess the nesting habitat value of the entire property and within a patch type, over time (see table 1).

<u>Focus 1.</u> Population Dynamics: Have resident populations of *G. t. sinuosa* and *M. m. santaecrucis* changed significantly over 5 years of observation at CCRS overall? If so, why?

For focus 1, Objectives 1.1 through 1.4 were answered using mist net data collected at CCRS from 1994 to 1998 and nest search data collected in 1997 and 1998.

<u>Objective 1.1</u> What are the documented population dynamics changes for Salt Marsh Yellowthroats and Song Sparrow populations at CCRS from 1994 to 1998?

This objective was addressed using mist-net data and nest search data. The data were presented graphically to depict the annual increase or decrease in the number of returning adult birds that had been recaptured and the number of juveniles that were captured during the months of March through August, from 1994 to 1998.

These numbers were modified and graphed again based on the number of females that were documented from the nest searches during the months of March through August, from 1997 to 1998. This modification yielded a graph depicting the maximum documented females and estimated individuals for both species that could have existed at CCRS during these months from 1994 to 1998.

<u>Objective 1.2</u> What is the nesting success (N_S) for Salt Marsh Yellowthroat and Song Sparrow populations at CCRS, as a whole and by patch type ("Old Reveg.", Overflow Channel", or New Reveg.")?

This objective was answered by using nest search data to calculate 'nest-building to fledgling' (Mayfield 1961; 1975) nesting success probabilities for each species from

1997 to 1998. Probabilities for each of 5 stages of nesting were presented as bar graphs for each species and each patch type.

<u>Objective 1.3</u> How might changes in local Salt Marsh Yellowthroat and Song Sparrow population dynamics from 1994 to 1998 be influenced by nesting success?

The answers to objectives 1.1 and 1.2 were used to address this objective. The Mayfield nesting success probabilities from 1997 to 1998 were applied to the graph depicting maximum potential annual increase or decrease in recaptured adults and juveniles to see how the nesting success of the two species has impacted their respective population dynamics. Both graphs were combined to show the extent to which nesting success has potentially affected both populations over time.

<u>Objective 1.4</u> Are the populations of Salt Marsh Yellowthroats and Song Sparrow populations at replacement at CCRS?

This objective was addressed by calculating and graphically depicting (1) the net annual replacement of adults by juveniles 1998 and (2) the juvenile: adult replacement ratios for 1994 using the mist-net data from objective 1.1. The graphs were used to determine whether replacement of either or both species was occurring annually at CCRS from 1994 to 1998.

<u>Focus 2.</u> Nesting outcomes: What nest factors are correlated with nesting success?

For focus 2, Objectives 2.1 and 2.2 were answered using mist net data from focus 1 and nest search and territorial mapping data collected during the months of March through August, from 1997 to 1998.

<u>Objective 2.1</u> Do nest densities correspond to nest success/non-success for each patch, Mayfield nesting success, or reproductive index values?

This objective was answered by graphically presenting (1) the frequency distribution of all nests encountered and proportions of successful and non-successful nests; (2) Mayfield nesting success probabilities broken down by bird species and habitat patch type; and (3) reproductive indices, applying the indices of reproductive success defined by Van Horne (1983) to the territorial mapping data and nest search data. All of the values for the nest criteria were broken down by habitat patch type and bird species on a per hectare basis.

Next, each habitat patch was ranked based on the nesting criteria. Again, these scores were evaluated per hectare to give a view of how relative nest density corresponded to the aggregate scores of each of the three habitat patch types.

<u>Objective 2.2</u> Based on nest search data how are nesting Salt Marsh Yellowthroat and Song Sparrow populations at CCRS being affected by nest parasitism and predation, as a whole and by patch type?

This objective was answered by graphing the leading causes of nest failure documented during nest searches and territorial mapping from 1997 to 1998. The graph depicts the number of nests that were observed to fail as a result of any one of five nest mortality factors in each of the three habitat patch types on the property.

<u>Focus 3.</u> How are population dynamics and nesting outcomes specifically related to each of the three habitat patch types ("Old Reveg.", Overflow Channel", or New Reveg.")?

All four data sets were used to answer objectives 3.1 to 3.4 in order to address focus 3.

<u>Objective 3.1</u> What average structural vegetative characteristics, leading nest plant cover and nest plant substrates are present within each of the three patch types at CCRS?

This objective was addressed by graphically presenting the proportions of leading nesting habitat characteristics for each species and each habitat patch type, from 1997 to 1998, using the vegetative habitat assessment data. Mean values for each vegetative habitat characteristic were calculated and presented in tabular form.

<u>Objective 3.2</u> Does nest success/failure correlate with the specific vegetation growing within a patch type?

This objective was addressed initially by graphically presenting the leading proportions of nest support and nest cover plant species for successful and non-successful nests.

Next, ANOVAs were conducted between and among nest location and successful/non-successful nests using the habitat data and nest search results from objective 2.1. to see if variation within or between patch types occurred do to more than chance alone.

Finally, Student's T-tests were conducted for each habitat characteristic that was found to vary significantly in the ANOVAs. The first test compared the two years of sampling to see if variation in vegetative growth or specific vegetation types was significant within each patch type from one year to the next. The second test compared variation in vegetative characteristics between the successful and failed nests in each habitat patch type to see if variation in vegetative growth or specific vegetation types was significant for failed or successful nests within each patch type. The results from all tests were evaluated to see what specific habitat characteristics appeared to correspond with nesting success/failure within a specific patch type and overall.

Objective 3.3 Are Salt Marsh Yellowthroat and Song Sparrow populations at CCRS positively or negatively correlated with restored habitat management strategies as a whole or by patch type?

Objective 3.4 Are the extent and timing of overflow channel mowing and debris control correlated with reproduction of the two species?

These objectives were addressed by considering the results of foci 1and 2 in light of historic and current restored habitat management and overflow channel management strategies for objectives 3.3 and 3.4, respectively.

Table 1. Overview of data acquisition and analytical methods used to address each thesis objective.

Objective	Mist-net	Nest search	Vegetative habitat	Territorial mapping	Data Presentation / Interpretation
1.1- What are the documented population dynamics?	X	X			Graphical presentation of (1) numbers of returning adults and juveniles of both species over time; (2) max. potential birds present based on the higher # of females documented through nest searches or mist-net recapture.
1.2- What are nesting success rates?		X			Calculate 'nest-building to fledgling' probabilities of survival based on the total days of egg and hatchling survival per nest of either species.
1.3- How is nesting success causing changes in population dynamics?	X	X			Nesting success probability applied to graph of max. potential birds present based on the higher # of females documented.
1.4- Are the two populations at replacement?	X				Graphical presentation of (1) net annual replacement of adults by juveniles; (2) juvenile:adult replacement ratios.
2.1- Do nest densities correspond with nesting success/failure?	X	X		X	View of all nesting success criteria broken down by habitat patch type and put in terms of density (value per hectare).
2.2- How is nesting and/or breeding affected by nest mortality factors?		X		X	Evaluation of leading nest failure causes among species and regions, based on territorial mapping and nest search data.
3.1- What leading nest plant cover and nest plant substrates are present within each of the three patch types at CCRS?			X		Graphical and tabular presentation of leading habitat characteristics and average vegetative habitat values.
3.2- Does nest success/failure correlate with habitat characteristics in each patch type?		X	X	X	Graphical presentation of nest substrate by successful/failed; ANOVAs and student's paired Ts of vegetative habitat values by location and by nest success.
3.3- How do above objectives define CCRS habitat restoration management?	X	X	X	X	Assessment of three patch types based on results of foci 1 and 2 in light of restored habitat management practices.
3.4- How do above objectives define CCRS overflow channel management?	X	X	X	X	Assessment of three patch types based on results of foci 1 and 2 in light of overflow channel management practices.

Data Collection

The methodology for this study follows that used by biologists conducting similar research at the Kern River Research Center (KRRC) (Spautz, H. 1997). These methods are widely used and therefore allow some comparison to the literature.

A. Mist-net Data Collection

Mist-net data collection was ongoing at CCRS from 1972 until 1998. Mist nets are composed of large rectangular, 5m x 10m, black corded nylon netting that is hung on two 5m tall aluminum poles and secured in place by guy lines. They mildly resemble a three-tiered volleyball net. Fifty "contract" (SFVWD mandated) mists nets were put up at specific locations and monitored throughout the CCRS property as depicted in the map of the study sites (see figure 1). Each mist net was opened 45 minutes prior to sunrise and left open up to 5 consecutive hours (weather depending). Nets were checked repeatedly for captured birds until the time they were closed. A typical net run occurred every 35-45 minutes and no net was left unchecked for any longer period. Captured birds were carefully extracted from the net immediately upon encounter and placed in a soft cloth bag, which was closed securely with a drawstring, and carried back to the banding station. The birds were then extracted one by one from the bags and processed as follows: If a US Fish and Wildlife bird band was not already present the bird was banded and the official USF&W band number was then recorded on a data sheet for each bird caught. Additional data were recorded on the same data sheet including species type, gender, age, breeding condition, amount of fat, weight, wing span, tail length, net location, and the date and time of capture. Females that were determined to be in breeding condition by the presence of a brood patch were returned and released at the net location where they were initially found to ensure that they would be able to find their nest and return to it to care for the young or incubate eggs as needed. All other birds were released close to the banding station as soon as they were processed.

B. Territorial Mapping

Mapping methodology developed by Ralph, et al. (1993), was used to map territories in the overflow channel and the "Old Reveg." and "New Reveg." sites at CCRS. Territorial mapping, was carried out through observation of birds and censusing of singing males. The mapping method is based on the territorial behavior of birds. In general, repeated visits were made (a minimum of 8) to observe bird behavior in the three sites during the breeding season. By marking the locations of observed and singing birds on a detailed map during at least 8 visits within a breeding season, it was possible to count the number of territories in an area and estimate the density of birds. A detailed map (known as a visit map) was drawn of the site at a 1:2000 scale before the first census (see figure 1). A survey map (1:20,000) and field experience was used in drawing. Boundaries of the area and landmarks such as edges between habitats, streams, roads, paths, buildings, big rocks and trees, were marked to include enough landmarks on the map to be able to locate the positions of birds accurately on the map. One copy of the map was used for each visit, reserving enough copies for making the species maps.

Because of differences in bird arrival and nesting times, the site visits covered a period long enough (8-12 weeks) to ensure that each territorial male was easily observable on at least three visits. The visits were evenly distributed at 2-3 times per week over the 18 week census period. The main census time was 5-10 a.m. when the birds sing most actively. During very warm weather the daily census time was prolonged to increase the opportunity to count birds that were generally less active. Successive visits were started at different randomly chosen points.

Frequently stops were made to "hunt" for simultaneous observations of different individuals of the same species, to listen, and to mark the birds on the map. When there was uncertainty as to whether there was only one bird or two, the area censused was revisited to reconfirm counts. Open areas were searched with binoculars.

C. Nest Searches

The timing and duration of territorial observation varied according to the timing and length of the breeding season and the frequency of egg laying which are slightly different for each of the two species. Any additional observations of territoriality were recorded during the process of nest searches. Reproductive Index variables that were gathered during nest searches included the number of weeks the territorial male or the territorial pair were present; nest building; laying; incubation of eggs; distraction display (given when the observer has approached an active nest); adults carrying food to presumed nestlings; evidence of fledging success (begging calls with an adult present near nest, fecal material on the edge of the nest) in either or both broods.

In order to analyze nesting success and mortality factors, the following evidence was recorded during searches of nests: brood parasitism, egg predation by cowbirds and predators, predation of young and nest abandonment. The incidence of nest parasitism and predation was noted using the following variables: number of eggs per nest that had been depredated; manner of predation; number of eggs replaced by cowbird eggs; number of eggs that hatched; number of eggs that did not hatch; number of young per nest that survived to fledge; and ratio of songbirds to cowbirds that hatched per nest. These important dates were also recorded: date nest was encountered, date first egg was observed, date first egg hatched, and date first chick fledged (see below for the method used to calculate these last two dates).

The process of locating and tracking nesting behavior of both bird species used by Spautz (1996) and Ralph, et al.(1993) began as soon as they started exhibiting nesting behavior, indicated by singing males establishing their respective territories, in early March. Nest searches overlapped with territory mapping when locating territories by watching singing males, but then expanded into waiting for cues to nest location by observing females. In general, nest building for Song Sparrows began by late March/early April. Salt Marsh Yellowthroats started nesting by mid-April, although in both cases some birds started earlier. Only the female constructs the nest and incubates the eggs. Thus, the most common way of finding most nests was by locating and following females, although males provided some cues. For Yellowthroats, towards the end of the season, nests were located by following a characteristic "chrr" (or "wren-like burr": Hofslund, 1959) call given by females at or near the nest. Some nests in the shrub layer were found by random search.

Since females tend to be extremely furtive during nest building, they were checked with binoculars, especially during and after long, direct flights, to determine if nesting material was being carried. Randomly assigned paths were used across plots to increase the probability of randomly encountering females near undiscovered nests. Birds with nesting material were followed from a distance of at least 15 meters to avoid disturbance, without interrupting long flights. Some birds tolerate nearby observers and behave normally, but most species are very wary of observers. If such behavior was indicated, birds were observed from a new position at a greater distance to avoid scaring them. During nest building, the female arrives with nest material and leaves without it from the same location several times. Such behavior is the main search pattern that was used to narrow the nest search within more defined spatial limits.

Most species renest after a nesting failure. Reconstruction usually begins within ten days; the earlier in the nesting cycle that failure occurred, the farther apart the nests are likely to be. Multi-brooded species may renest in as little as 8 days after fledging. Sometimes the female begins nesting while the male is still tending the fledglings of the previous brood.

According to the literature, (Bent, 1953;1996) Song Sparrows are capable of 2-3 broods while Yellowthroats are capable of brooding 1-2 times. However, it should be noted that even if more than one brood was laid it was virtually impossible to insure whether the same bird was being observed from one brood to the next. Therefore, while it is accepted that each bird is capable of brooding at least twice, in this thesis it was always assumed that each new or different nest observed was considered the product of a new and different female.

Once nests were located, their contents were monitored every two days, except when the exact day of hatching needed to be ascertained. If the nest was found with hatchlings already in it monitoring took place on a daily basis until fledging occurred, in order to count backwards to the day when the first chick hatched (using a post-incubation period constant of eight days). Careful attention to checking nests is critical for data quality, because the number of days that nests have eggs or young is used to calculate daily mortality rates, the most effective measure of nest success (Mayfield 1961,1975). Careful and detailed observations were recorded if a nest predation event was observed. If the nest appeared inactive from a distance, it was approached to verify predation. If the eggs or young appeared to be gone, the nest structure and immediate area were checked for evidence. Any evidence (e.g. shell fragments, punctured eggs, hole in nest, nest torn up) was noted.

As young approach fledging, nests were observed less often and from a distance, because young may fledge unusually early, e.g. day 7 or 8, especially when disturbed (Spautz, pers. comm., Hofslund, 1959). When the young fledge, they commonly perch on the edge, flattening it, and leave fecal droppings in, or on the edge of, the nest. These would indicate possible successful fledging. Attempts were made to verify success by seeing fledglings or by hearing adult alarm calls or begging calls of the young. Fledglings normally do not move very far in the first couple of days.

While nest searches were being conducted, additional nest mortality factor variables were noted including: severe weather conditions, physical presence of brown-headed cowbirds and nest predators, such as raccoons, scrub jays, red foxes, feral cats, snakes and small mammals.

D. Vegetative Assessment

One week after fledging or failure, habitat variables were measured in a 80 m^2 plot centered on the nest (Spautz, 1997; James and Shugart, 1970; Noon, 1987). The plots were delineated using two 10 m. long ropes set out along the north-south and east-west directions, forming a circle of radius 5 meters. Measurements included nest height, species and height of support plant; distance to creek, overflow channel, coyote bush/shrub edge, riparian forest edge, and open ground; percent nest canopy closure; height and size of the patch at 2 scales; foliage density (Noon, 1987); distance to and characteristics of the nearest woody vegetation; distance to and characteristics of the nearest tree of dbh > 3 inches; and percent cover of 7 vegetation categories (grass, forb, tree, brush, bare ground, dead forb, and dead herb stalk).

Twice during the sampling period (once at mid-season and once at the end) random vegetative plots were sampled from each of the three sites. All but the nest specific habitat measurements (1-7, Appendix B) were measured for each of the random plots established at each site.

Results

Focus 1: Population Dynamics

This section is a description of the analysis and results of the mist-net and nest search data used to address focus question 1; Have resident populations of *G. t. sinuosa* and *M. m. santaecrucis* changed significantly over 5 years of observation at CCRS? If so, how?

Objective 1.1: Documented Changes in Population Dynamics

Long-term and year-to-year demographic trends, including breeding bird site fidelity and fluctuations in fledgling (juvenile) productivity were plotted on a series of curvilinear graphs depicting:

(1) numbers of returning adults and juveniles of both species over time; and

(2) maximum potential birds present based on the higher number of females documented through nest searches or mist-net recapture.

The relative fluctuation in the local *G. t. sinuosa* and *M. m. santaecrucis* populations over 5 years was initially assessed by plotting the number of individuals captured over time. For simplicity's sake, Salt Marsh Yellowthroats are indicated by its international banding code of "COYE" and Song Sparrows by "SOSP" on this graph and in all figures from this point forward. The number of juvenile Song Sparrows captured from year to year drastically declined in both 1994 and 1996 (figure 2). Salt Marsh Yellowthroat juveniles increased until 1996 and then went down again to an all time low of 7 individuals in 1998. Salt Marsh Yellowthroat adult numbers, however, appear to have remained relatively stable, whereas Song Sparrow adult numbers dipped slightly in 1995 and have been on the rise since then.

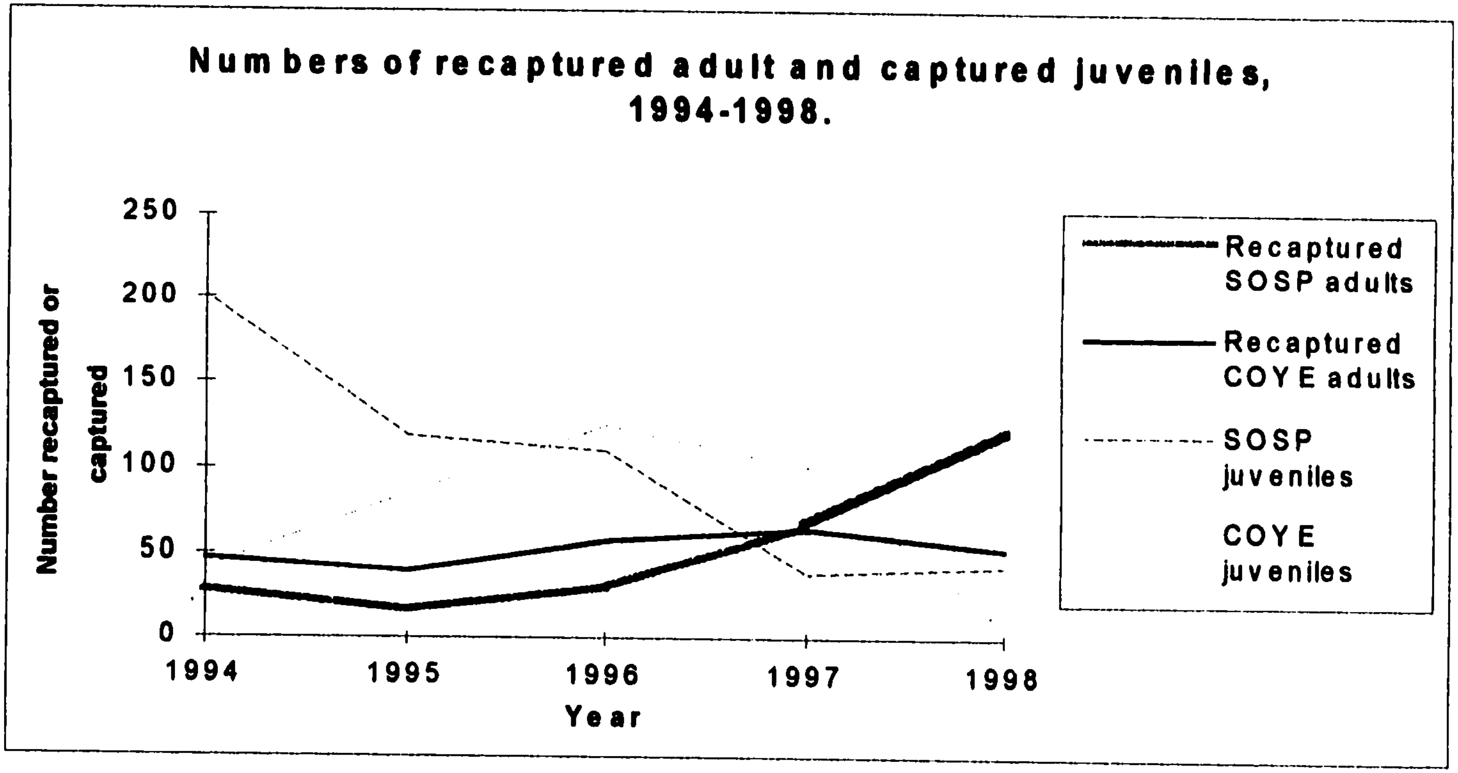

Figure 2. Numbers of recaptured adults (males and females) and captured juveniles by mist-net at CCRS, 1994-1998.

To draw valid conclusions based on the relative fluctuations in the graphs depicting number of birds captured it was necessary to evaluate the banding effort, the number of banding hours that were logged on a monthly basis from 1994 to 1998. Data on the number of banding hours per net at CCRS for 1998 has not been entered yet and therefore could not be analyzed for this thesis. However, it is apparent from the banding hour data for the months of March through August, from 1994 to 1997, that banding effort increased on average (See figure 3) . Although this trend helps explain increases in SOSP adults, decreases seen in COYE adults and all juveniles captured over time at CCRS was not a result of decreased banding effort during the years of 1994 to 1997.

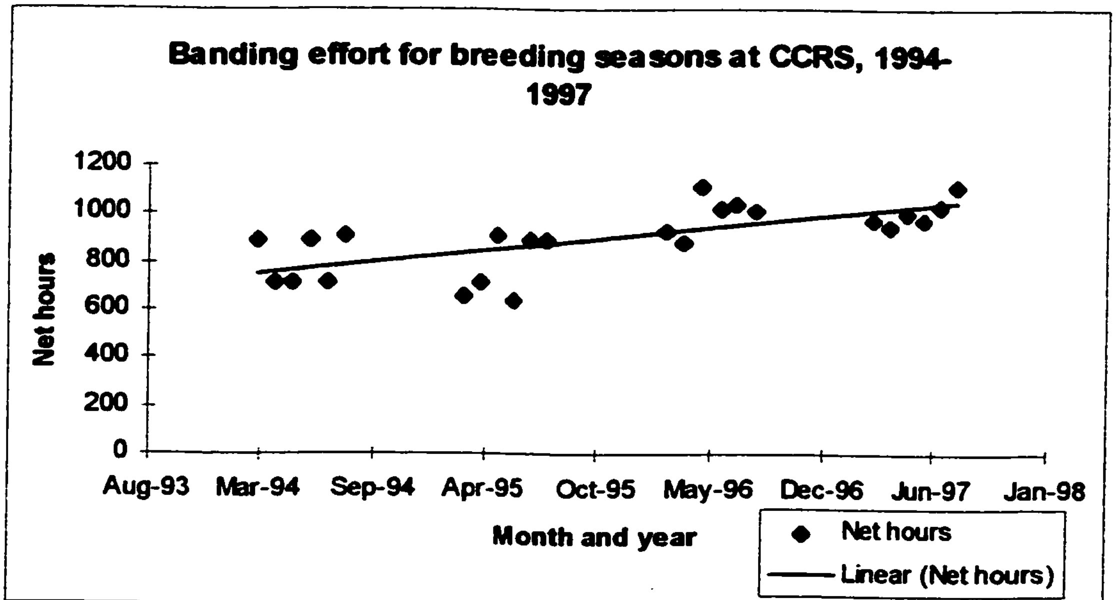

Figure 3. Overview of banding effort at CCRS from 1994-1997.

The view in figure 2 is cursory at best, and no definitive conclusions about the stability of the two populations can be made without considering both the current nesting success and the relative breeding site fidelity for each species. Capture and release methods only document those birds that have been near the nets. Because female Salt-Marsh Yellowthroats are known to be furtive and reticent to leave their nest, a true documentation of female population components may not be reflected in the mist-net data. Similarly, because juveniles are known to disperse extremely rapidly after fledging, the true number of juveniles that have been produced at CCRS over time may not have been properly documented through mist-net capture. For these reasons, the observed breeding females and the observed nesting success rates from nest searches from March through July of 1997 and 1998 were used to derive maximum potential population estimates. 1997-1998 numbers were also used to estimate the numbers for 1994-1996 when no nest searching occurred.

The numbers of breeding females for the years 1994-1996 were extrapolated by calculating n_i in the following equation, adapted from Tanner (1978). In this calculation:

> $r_{97\text{-}98}$ = the average number of females recaptured by mist-netting from 1997-1998; $n_{97\text{-}98}$ = the average number of nesting females observed while nest searching from 1997-1998; r_i = the annual average count of mist-net recaptured adult females for each year from 1994-1996; and n_i = the extrapolated number of breeding female adults observed annually.

For this calculation, it is assumed that density of nesting females does not significantly affect their recapture rate.

Equation 1:

$$n_i = r_i \left(\frac{n_{97\text{-}98}}{r_{97\text{-}98}}\right)$$

Table 2 shows the resulting extrapolated numbers for 1994-1996 when Equation 1 was applied to the mist-net and nest-search data.

Table 2. Recaptured and observed Female Salt Marsh Yellowthroats and Song Sparrows at CCRS from 1994-1998.

Year	Recaptured SOSP females	Breeding SOSP females (*1994-1996, extrapolated)	Recaptured COYE females	Breeding COYE females (*1994-1996, extrapolated)
1994	10	5 *	16	27.2 *
1995	5	2.5 *	9	15.3 *
1996	7	3.5 *	13	22.1 *
1997	20	4	14	13
1998	26	19	6	21

Next, in order to estimate what the maximum population size could have been from 1994-1998, the assumption was made that there is a 1:1 sex ratio of males:females for both songbird species and that each female lays an average clutch of four eggs, which could potentially produce nestlings (Bent, 1953;1996). The total numbers for each year were estimated using the formula 6n, where n = the maximum number of females that were documented or extrapolated from mist-recapture or nest searches, annually. Because it is likely that some of the same birds were documented both during nest searches and mist-netting in 1997 and 1998, the higher of the two figures was chosen to represent the maximum numbers of females that have been breeding at CCRS from one year to the next. For Song Sparrows, the mist-net data were higher over both years so the mist-net data were always used. Salt Marsh Yellowthroat nest-search data were much higher in 1998 but slightly lower in 1997 which results in a slightly higher average. The nest-search data or extrapolations were thus used for all years except for 1997, where the mist-net data was chosen. These assumptions generally bias toward an overestimation of population size. They are thus used to derive a "conservative" estimate of the population decline at CCRS from 1994 to 1998.

Using the maximum number of females that could be extrapolated from either mist net or observation data, the population projection changes somewhat from figure 2. Salt Marsh Yellowthroat populations are generally in decline (see regression line, figure 4). Song Sparrows numbers do not decline following the period of mowing of the overflow channel and instead increase markedly, whereas even maximum potential Salt Marsh Yellowthroat numbers still incur a substantial decline during the same time period (1996-1997). Although the increased banding effort after 1996 could have been a factor in Song Sparrow population increase, documented Song Sparrow population increases far outpace the slight concurrent increases in banding efforts. The Salt Marsh Yellowthroat numbers, which were mostly extrapolated from the higher nest-search numbers, generally could not have been influenced by banding effort.

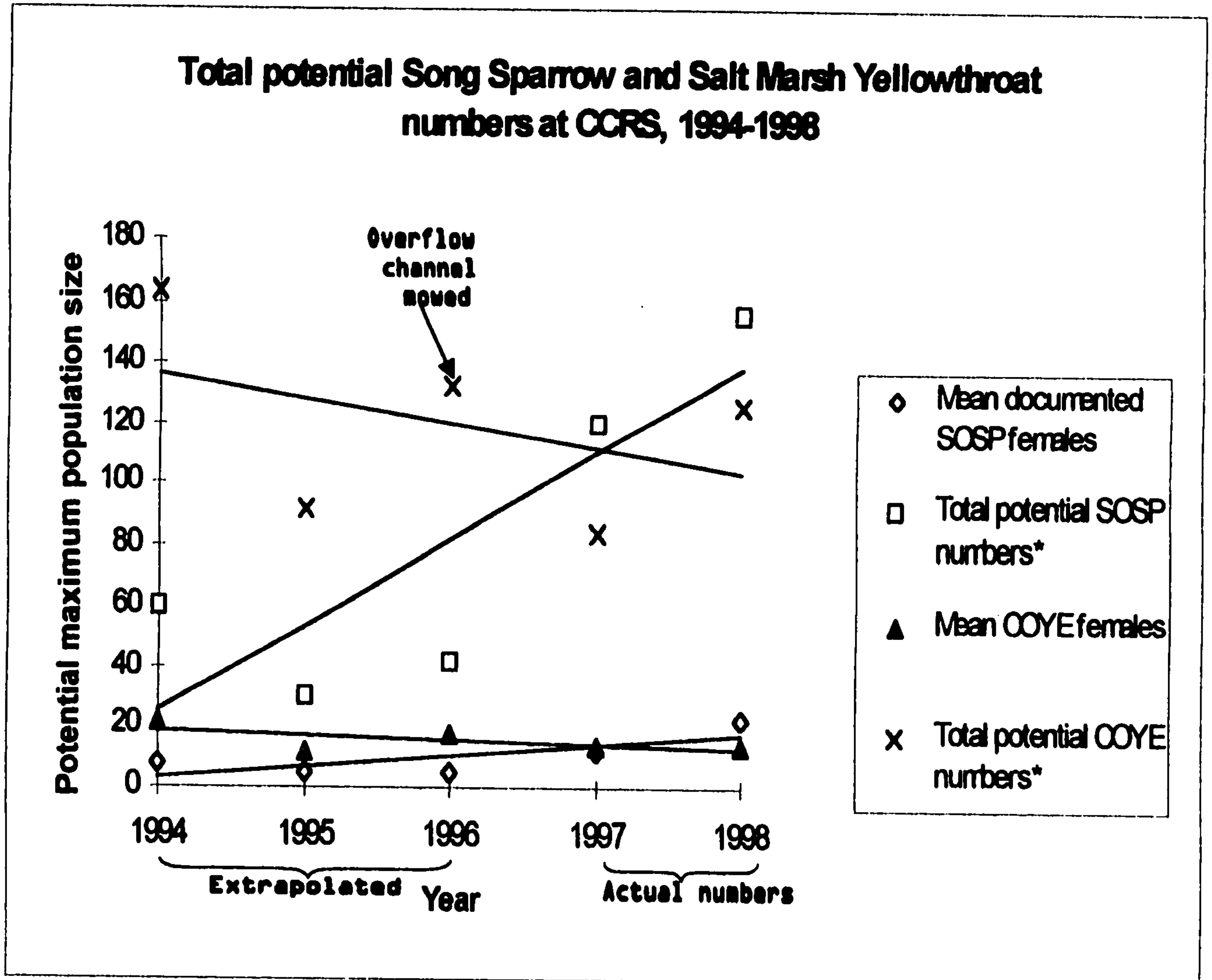

Figure 4. Maximum potential numbers of Song Sparrow and Salt Marsh Yellowthroats at CCRS, 1994-1998, based on female numbers only.

Objective 1.2: Mayfield Nesting Success Probability

When nest data were collected, each nest was recorded as successful or unsuccessful, parasitized or not, depredated or not. The nest day unit exposure for each egg success were then calculated using the Mayfield (1961; 1975) method of calculating nest success, which is based on total days of observation per nest. 'Nest-building to fledgling' probabilities of survival are calculated based on the total days of egg and hatchling survival per nest of either species. The total number of days that the exposed nest was observed were documented during nest searches. The probability of an egg surviving to the fledgling stage was calculated for each of the nests observed by adding all days that an egg was observed to survive in the nest (starting with the first egg date) plus all the days that the nestlings were observed surviving in the nest. The date the first egg was laid (first egg date) was calculated for each nest using 12 days as the length of incubation (Hofslund, 1959; Stewart, 1953; Stokes, 1996). If a nest was encountered in the middle of incubation, the first egg date was derived by counting backwards from the day of hatching. After all nest days had been documented, the probability for egg survival during incubation was multiplied by the probability of the nestling survival during the hatching period, which was again multiplied by the probability of the nestling survival to fledgling. These calculations yielded the probability of each egg produced at the start of incubation to produce a fledgling.

As indicated by the 'Egg to Fledgling' stage probabilities in both figures 5 and 6, nesting success has improved somewhat from 1997 to 1998, and an increase in overall Mayfield nesting success probability from 0 to 7% was achieved for both species.

However, while overall success improved from one year to the next, there was a noticeable decline in the probability of nest survival through the hatching stage, from 1997 to 1998. The improvement in probability of survival through the nestling stage contributed to the increase in overall nesting success probability, in 1998.

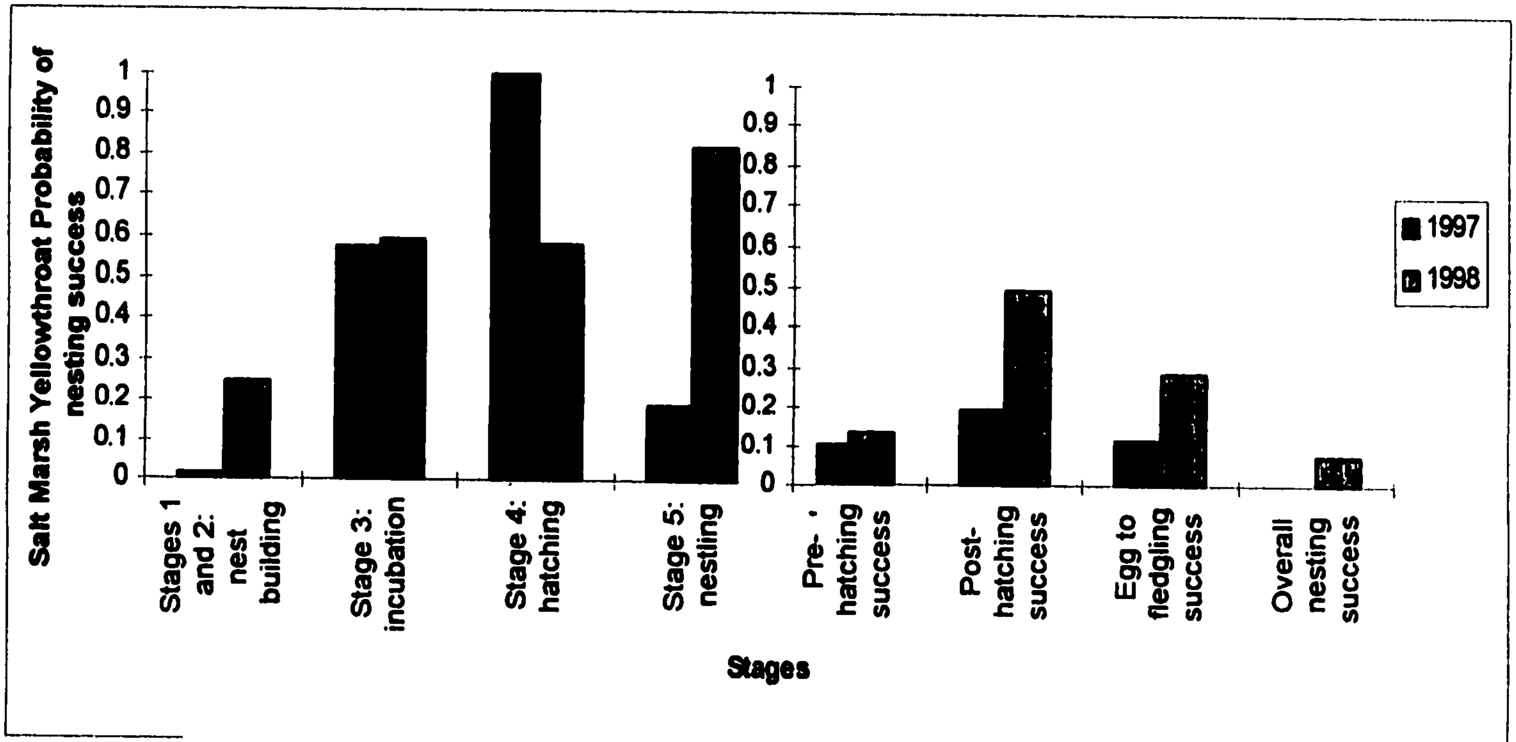

Figure 5. Salt Marsh Yellowthroat Mayfield nesting success probabilities at CCRS, 1997-1998.

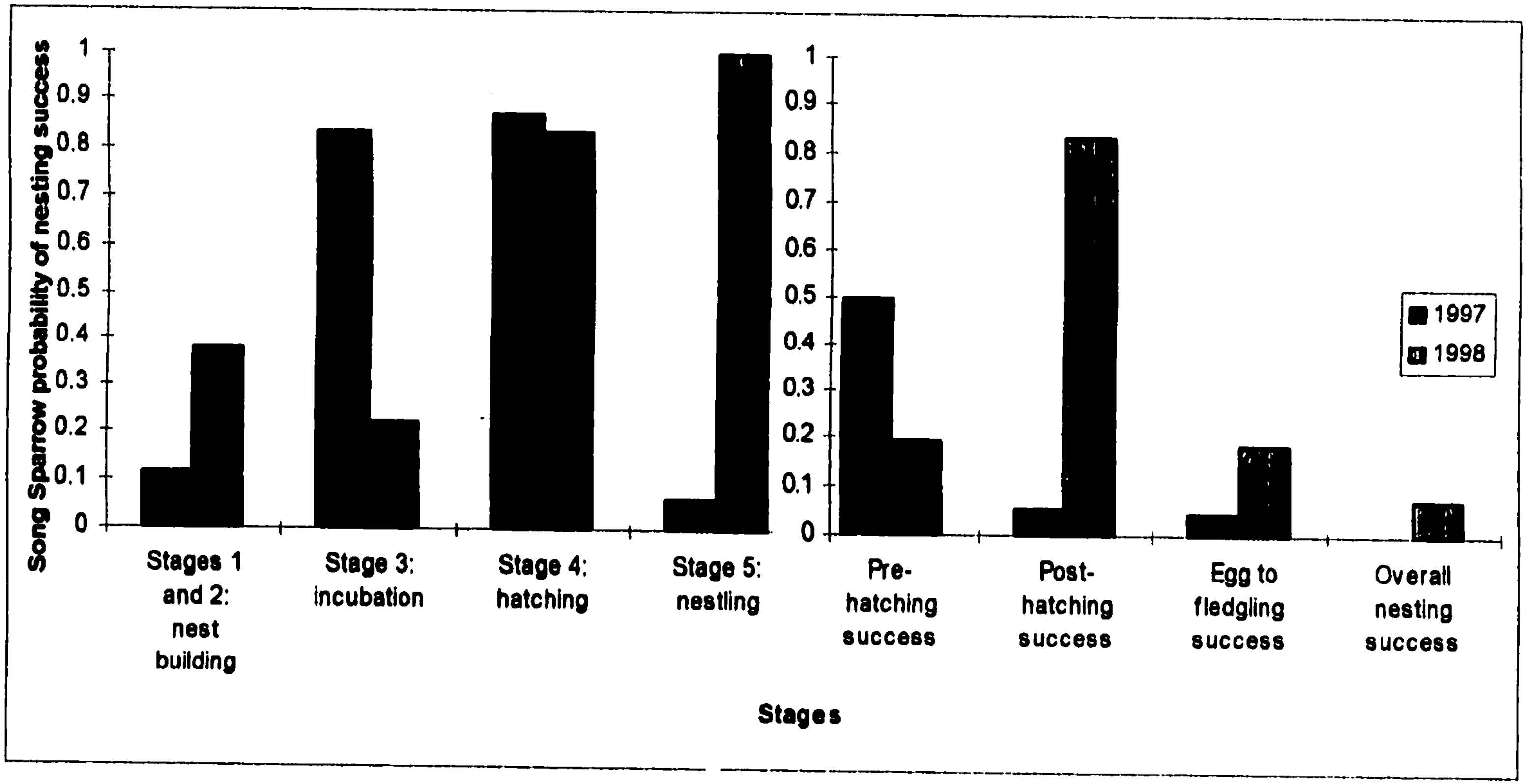

Figure 6. Song Sparrow Mayfield nesting success probabilities at CCRS, 1997-1998.

Objective 1.3: Mayfield Nesting Success Applied to Potential Numbers

The mean Mayfield 'nest-building to fledgling' nesting success probabilities for each species in 1997 and 1998 were then applied to the conservative estimate in figure 4 to illustrate how current reproductive success rates have functioned to effectively replenish or reduce the population on an annual basis. The impact of nesting success rates on the maximum population size over time was depicted by readjusting the total maximum numbers of individuals in figure 4 by the current Mayfield nesting success probabilities for each species. As described above, for objective 1.1, 4 out of 6, or 2/3 of the maximum potential individuals were assumed to be fledglings and 2 out of 6, or 1/3, were assumed adults. For this analysis, the maximum potential numbers were readjusted based on current nesting success rates as follows: the average number of eggs per female used in figure 4 was multiplied by the mean Mayfield nesting success probabilities for both species from 1997 to 1998 to derive maximum potential fledglings. These calculations yielded the maximum potential number of fledglings for each year from 1994 to 1998. These totals were added to the maximum potential numbers of returning adults, or 1/3 of the total maximum individuals in figure 4 for each year.

More succinctly, because each female was assumed to produce 4 eggs, that number was discounted for Mayfield nesting success probability to fledge according to the following equation:

Equation 2: $$N_{max} = (4NS)\, n + 2n$$

Where N_{max} = the maximum annual population number for each species; NS = Mayfield nesting success probabilities; and n is the number of females.

Based on this readjustment, it is apparent that the nesting success rates drastically lower any potential population increase that was hypothesized. This effect is particularly striking in the Song Sparrow population which shows very little increase in readjusted numbers when compared to potential numbers. This minor increase becomes even less significant when increased banding effort from 1996 to 1998 is accounted for.

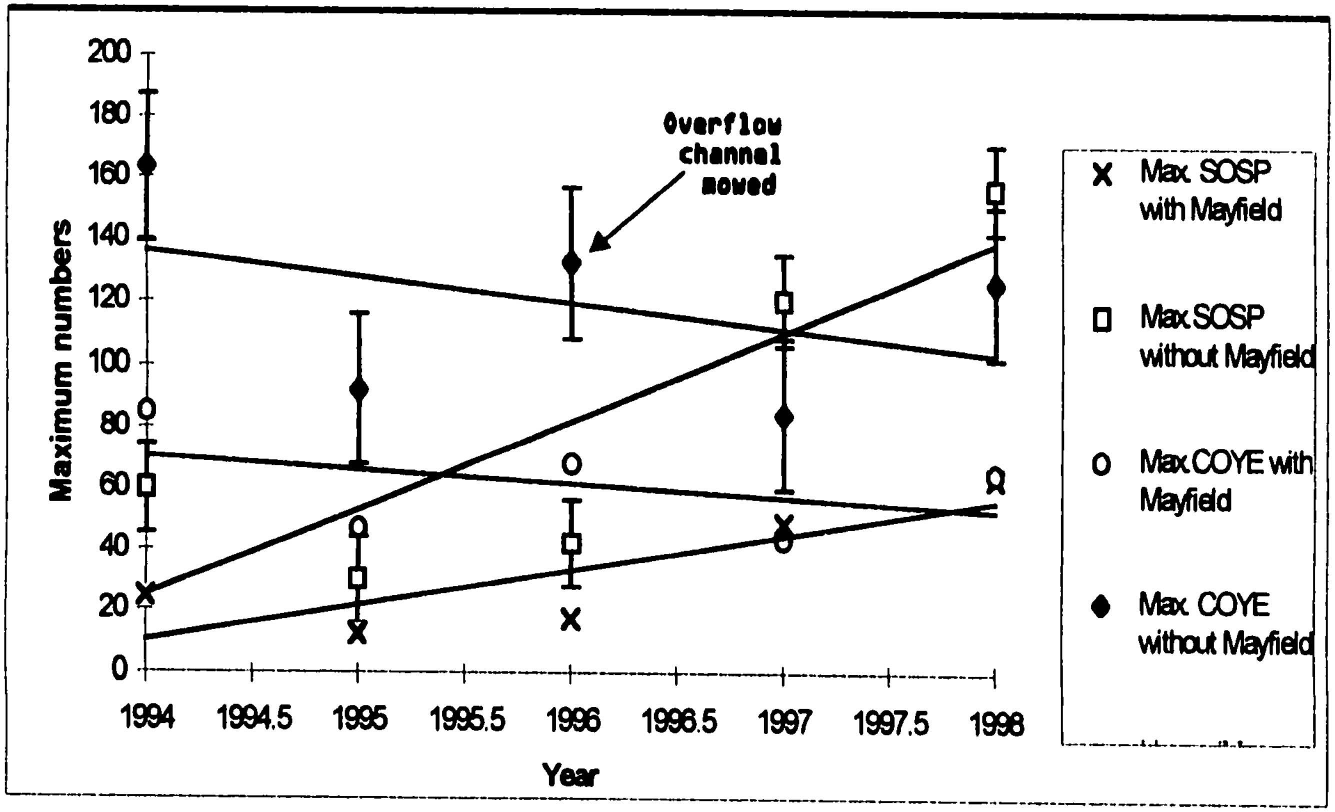

Figure 7. Readjusted maximum potential numbers of Salt Marsh Yellowthroats and Song Sparrows, at CCRS from 1994-1998, based on Mayfield nesting success.

Objective 1.4: Replacement

Conclusions about how the juvenile birth rate contributed to a net annual local population increase or decrease were made based on the mist-netted numbers of each population component over the five year time period.

Method 1: The annual number of juveniles captured by mist-netting was subtracted from the number of adults that were recaptured once by mist-netting.

Using the difference between adults and juveniles, the population replacement appears to have declined markedly for both species since 1996, the year that the overflow channel was mowed. Song Sparrow population replacement has trended downward since 1994, and dropped below zero in 1997. Salt Marsh Yellowthroat replacement declined after 1996 and dropped below zero in 1998 (see figure 8).

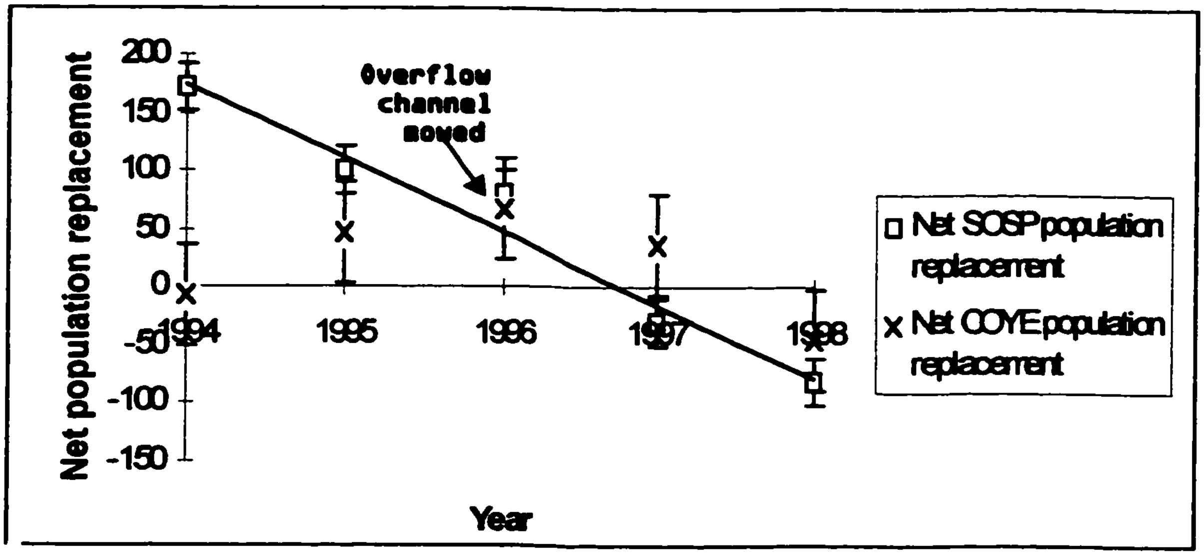

Figure 8. Net documented population change for Salt Marsh Yellowthroats and Song Sparrows, CCRS, 1994-1998. The net annual replacement of adults by successfully fledged juveniles was derived by subtracting the number of captured juveniles from the number of recaptured adults for each year at CCRS during the breeding season from 1994 to 1998.

Method 2:

Finally, Objective 1.4 was also addressed by using the following formula to estimate replacement, adapted from Tanner (1978).

Equation 3:

$$\text{Is } \frac{F_{i,\, i+1, \ldots 1998}}{N_{i,\, i+1 \ldots\ldots 1998}} > 1?$$

where $F_{i,\, i+1, \ldots 1998}$ = the annual number of fledglings documented by mist-net capture at CCRS from 1994 to 1998 and $N_{i,\, i+1 \ldots\ldots 1998}$ = the annual number of adults documented by mist-net recapture at CCRS from 1994 to 1998.

Using juvenile capture and adult recapture numbers from the mist-net data, the ratios of total young captured annually (F_i) to total numbers of returning adults that were recaptured from year to year (N_i), indicate that the numbers of returning adults of either species in 1998 were not being replaced annually by the numbers of fledglings that were being produced (see figure 9). In 1997 the Song Sparrow population was not replacing itself, and was in fact lower than the replacement ratio for Salt Marsh Yellowthroats. In the five years of documentation, only the Salt Marsh Yellowthroats ever exhibited an increasing replacement rate. This slight increase in F_i:N_i occurred in the years prior to mowing of the overflow channel (1994-1996). Neither population was replacing itself in 1998.

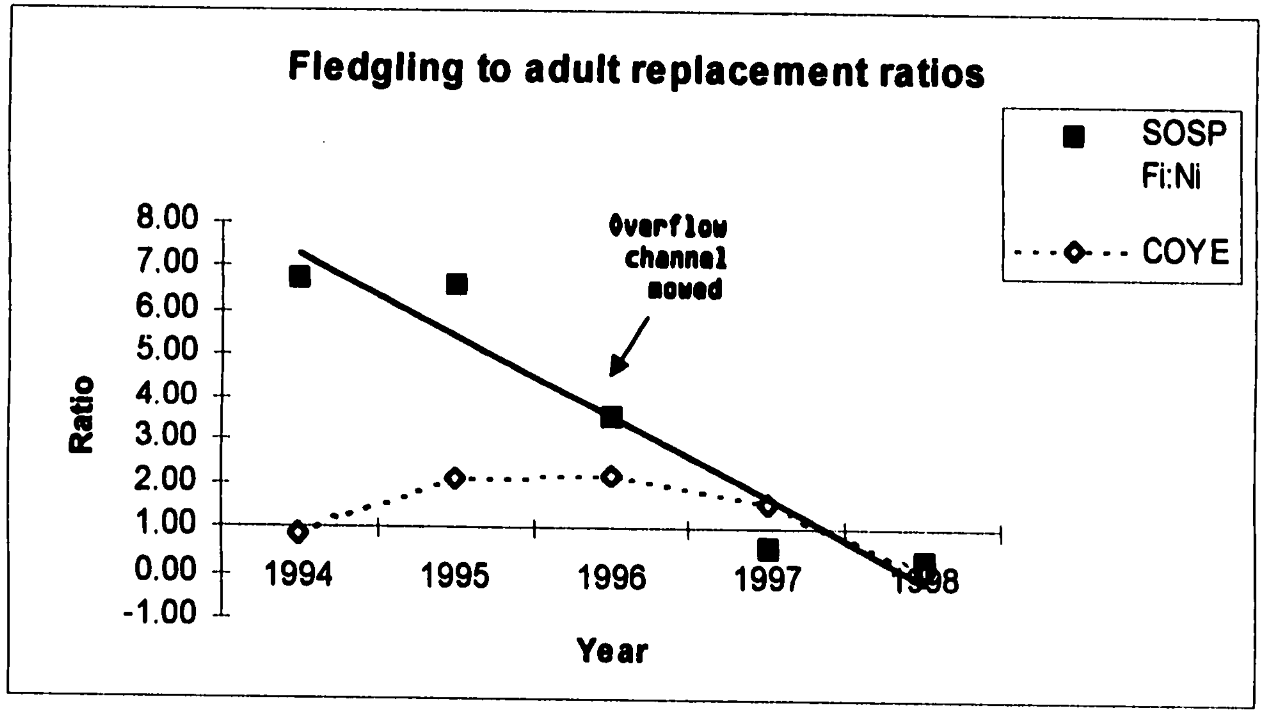

Figure 9. Fledgling (F_i) to adult (N_i) replacement ratios for Salt Marsh Yellowthroats and Song Sparrows at CCRS, 1994-1998. The fledgling to adult replacement ratio was derived by dividing the number of juveniles that were captured annually by the number of adults for each of the two species that were recaptured annually. Replacement was indicated when ratios were higher than 1.0.

Focus 2: Nesting Outcomes

This section is a description of nesting frequency distribution, proportions of successful/ unsuccessful nests, Mayfield nesting success probability, reproductive index, and nest mortality factor analyses and results and how they answer focus question 2, Is CCRS acting as a source or a sink for these species?.

Objective 2.1: Nest Density and Nesting Success Criteria

Thesis objective 2.1 asks, Do nest densities correspond to nest success/non-success for each patch, Mayfield nesting success, or reproductive index values? This question was addressed by graphing: (1) the frequency distribution of all nests found in each of the three patch types; (2) proportions of successful and non-successful; (3) nests Mayfield nesting success probabilities calculated in objective 1.2; and (4) reproductive indices, applying the indices of reproductive success defined by Van Horne, et al. (1983) to the territorial mapping data and nest search data. Next, each habitat patch was ranked based on these nesting criteria. The proportions of successful and unsuccessful nests were graphed by patch type and species. The Mayfield nesting success was calculated for all nests in each patch type and presented graphically by year. The Reproductive success, an assessment of the overall utility of each habitat patch for reproduction, was calculated by ranking observations of each nesting pair according to an index for reproductive success developed by Van Horne, et al. (1983). Refer to Table 3, below.

The frequency distribution was compared to these ranks to see if relative nest density appeared to correspond with higher or lower ranks of the nesting criteria in any or all of the three habitat patch types.

A. Nesting frequency distribution

No nests of either species were encountered in "Overflow Channel" in 1997 (see figure 10). Salt Marsh Yellowthroats had the highest number of nesting attempts for either species that year. A higher proportion of nests for both species combined were encountered in "Old Reveg.". Salt Marsh yellowthroats yielded the highest frequency of nests per hectare in both "Old Reveg." and "New Reveg.". More Salt Marsh Yellowthroat nesting attempts were made in "Old Reveg." than "New Reveg." in 1997. To the contrary, Song Sparrow nests were found in slightly higher proportions in "New Reveg" than "Old Reveg." in 1997.

Few nests were located in "Overflow Channel" in 1998 relative to the other 2 habitat patch types, although it is the largest habitat patch type. "Old Reveg." yielded the highest frequency of nests for both species combined again in 1998, despite the fact that it is half the size of the other two habitat patch types. The nests of Salt Marsh Yellowthroats were encountered with exactly the same frequency in both "Old Reveg." and "New Reveg." both years. Likewise, proportions of both Salt Marsh Yellowthroat and Song Sparrow nests were equally distributed in "Old Reveg." and "New Reveg." in 1998.

B. Proportions of successful/ unsuccessful nests

The proportions of successful and unsuccessful nests depicted in figure 10 are based only on the nests which had documented evidence of nest success or failure. No successful nests were documented in any of the three habitat patch types in 1997. There were more documented successful nests in "New Reveg." than "Old Reveg." in 1998 but

"Overflow channel" had the highest proportion of successful Salt Marsh Yellowthroat nests that year (see figure 10).

All 13 Salt Marsh Yellowthroat nests and all 6 Song Sparrow nests encountered in 1997 failed. In 1998, Salt Marsh Yellowthroats had the highest proportion of successful nests, 9 out 21 attempts (43%), while Song Sparrows had only 7 successful nests out of 25 (28%) attempts. Although more nesting attempts were made in "Old Reveg.", this habitat patch consistently yielded the highest proportion of failed nests for both species over both years.

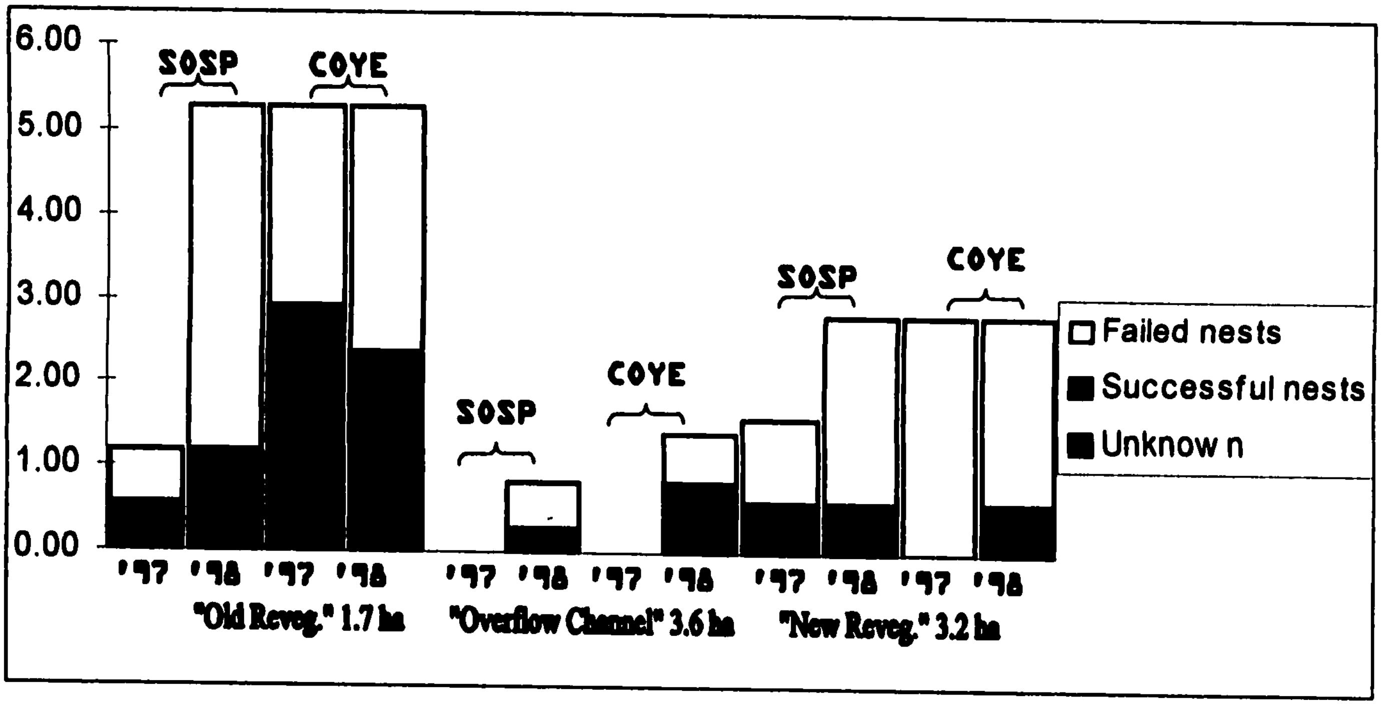

Figure 10. Frequency distribution and proportions of failed and successful nests for Salt Marsh Yellowthroats and Song Sparrow nests at CCRS. The number of nests encountered per hectare each year are depicted in each of the three patch types.

C. Mayfield nesting success and frequency distribution

Mayfield nesting success probabilities are based largely on the number of egg or nestling survival days in the nest rather than the actual documented success of a nest to produce one or more fledglings. Because Mayfield nesting success is a measure of nestling survival over 5 defined nesting stages from 'egg laying' to 'fledging' the undoubtedly lower number of nests that were actually documented as successful based on observation of fledglings will not be reflected by Mayfield nesting success probability. These criteria are entirely separate entities and therefore cannot be compared to one another.

Evaluating each patch for its nesting success proportions, "Old Reveg." produced an inconsequentially low Mayfield probability of nesting success in 1997 and no successful nests in 1998 (see figures 11 and 12). In 1997, "New Reveg." had the lowest nesting success probabilities throughout all stages. "New Reveg." did not produce any successful nests in 1997, but in 1998 the second highest Mayfield nesting success probabilities occurred there. Although no nests were documented in 1997 within the overflow channel, in 1998 "Overflow Channel" produced the highest probabilities of nesting success for all stages.

The greatest difference in Mayfield nesting success probabilities in 1997 occurred during the incubation stage of nesting. "Old Reveg." nests yielded a 0.83 probability of survival at this stage, while "New Reveg." yield 0.57. The greatest mortality occurred during the nesting stage in 1997, whereas in 1998 the greatest mortality occurred during the nest building and egg laying stages. The greater incidence of nest mortality in the nest-building and nestling stages in 1997 and the incubation stage for "Old Reveg." in 1998 are reflected in figures 11 and 12.

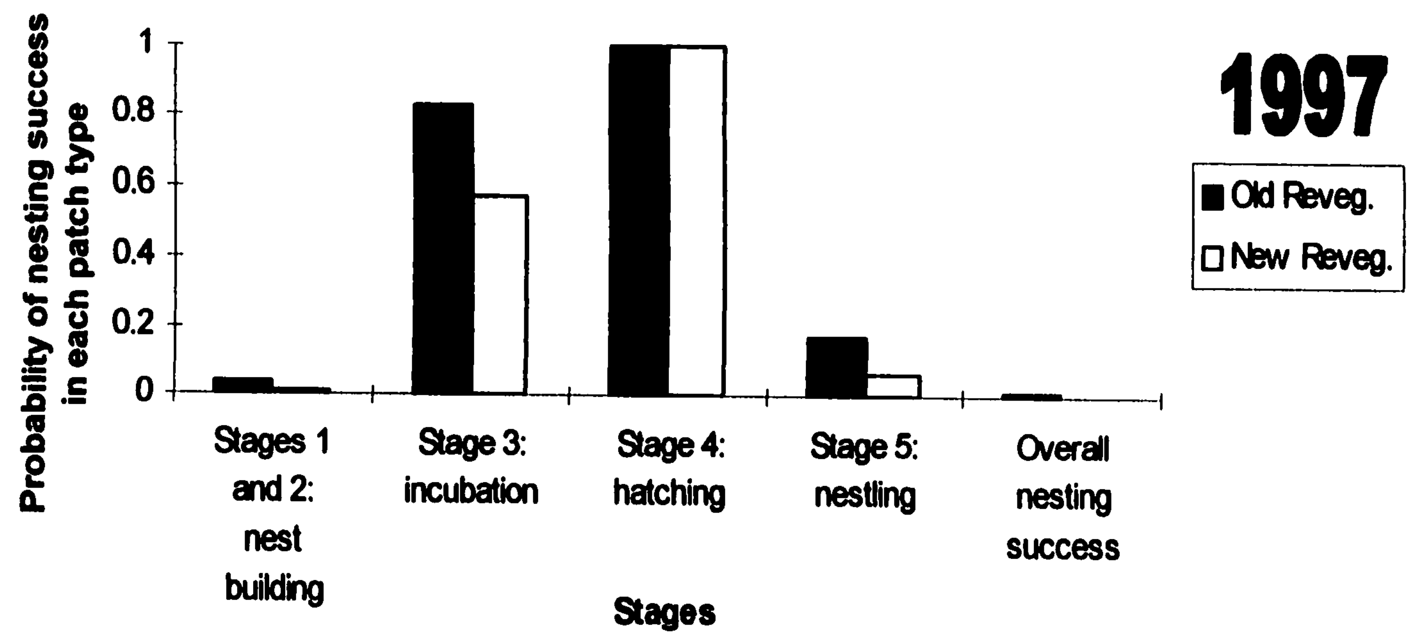

Figure 11. Mayfield nesting success probabilities for each site ("Old Reveg."and "New Reveg.") at CCRS, 1997.

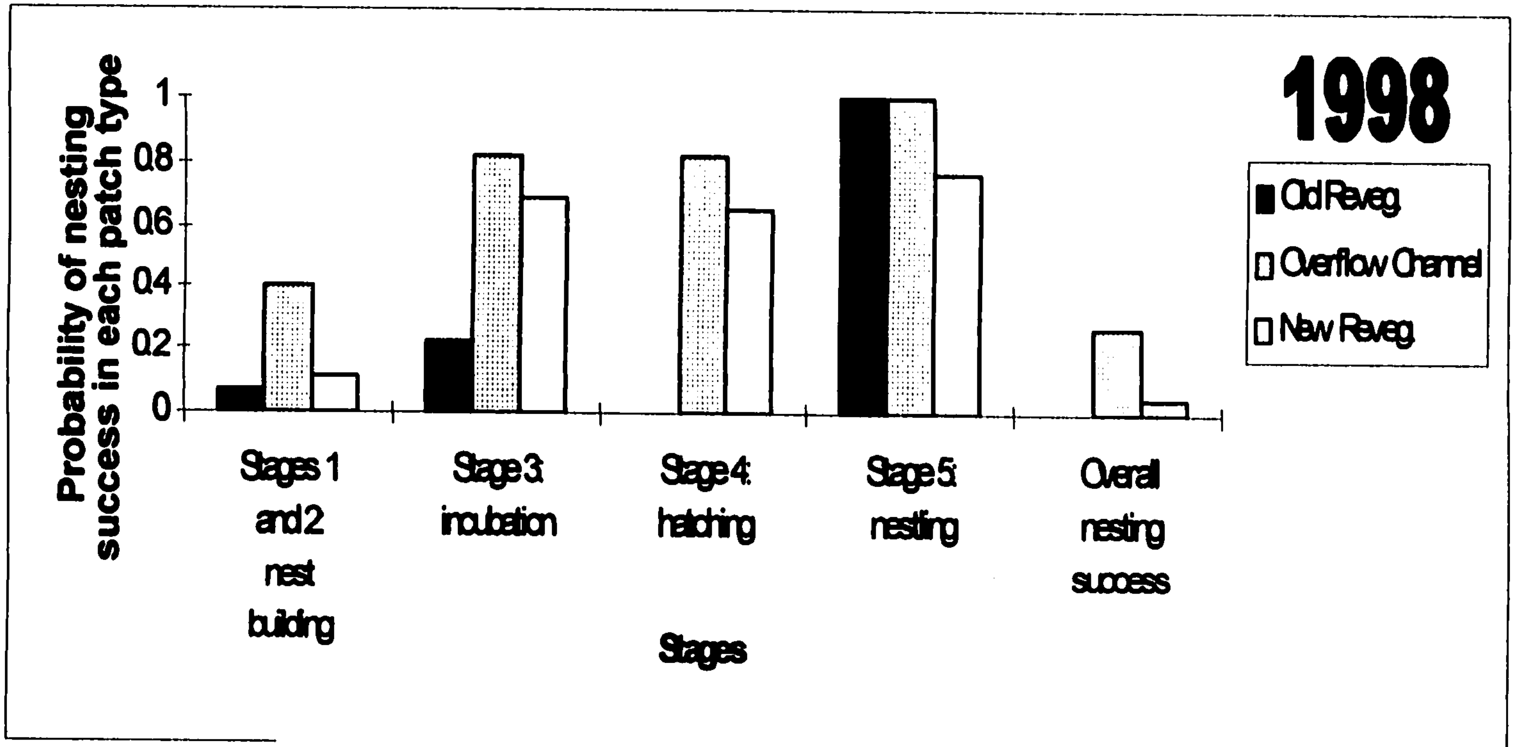

Figure 12. Mayfield nesting success probabilities for each site, CCRS, 1998.

D. Reproductive success

Reproductive success is a broader assessment of the overall utility of each habitat patch for reproduction by each species. It was calculated using an index for reproductive success developed by Van Horne (1983). The reproductive success of each nesting pair was ranked according to the definitions in Table 3. The highest level of success is indicated by the highest numbered definition, number 7 : 'evidence of fledging success in both broods'. Ranks were assigned to all nesting pairs for which such evidence could be documented. The ranks were pooled for each habitat patch to determine its relative capacity to provide suitable nesting habitat for each species.

Table 3. Reproductive index rankings for songbird species at CCRS (Van Horne, 1983).

Rank	Definition
1	Territorial male present 4+ weeks.
2	Territorial male and female present 4+ weeks.
3	Pair found nest building, laying, or incubating eggs or giving distraction display.
4	Adults carrying food to presumed nestlings.
5	Evidence of fledging success in at least one brood.
6	Evidence of fledging success in either brood, plus evidence of nestling success in other brood.
7	Evidence of fledging success in both broods.

Figure 13 gives the results from ranking of species and sites based on Van Horne's criteria for reproductive success when applied to all nesting pairs documented throughout the two nesting seasons. Each rank was divided by the area (ha) of its respective habitat patch in order to correct for size. For both species, "Old Reveg." ranked highest in terms of breeding habitat value (see figure 13). This is especially true for Salt Marsh Yellowthroats in 1998. With the exception of Song Sparrows in 1998, "New Reveg." yielded the next highest ranking reproductive index for all other breeding birds encountered there over both years. Although the overflow channel was the lowest ranking area for both species in 1997, the higher scores in 1998 indicate that the nesting habitat value improved markedly for both species, especially Song Sparrows, within one year of vegetative growth. When both birds are compared it is clear that the Salt Marsh Yellowthroats preferred "New Reveg." most for breeding in 1998, while Song Sparrows preferred to nest in "Old Reveg.", especially in 1998.

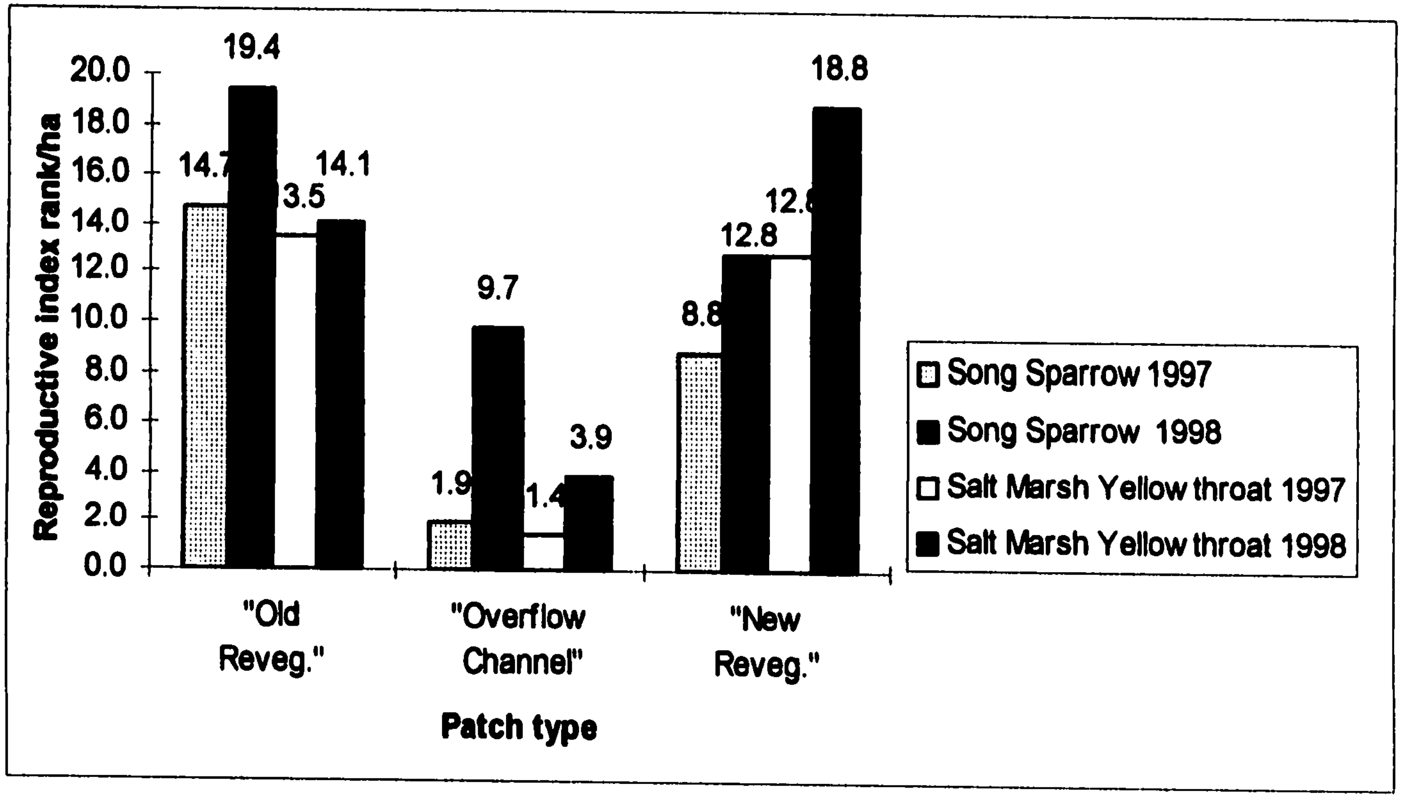

Figure 13. Results for ranking of reproductive index per hectare for species, year, and patch type.

E. Comparison of aggregated nesting success criteria for both species and patch types

Table 4 ranks habitats for each of the four criteria for nesting success, or N_s, with lower scores signifying better or more valuable habitat and higher scores signifying less valuable, lower quality, habitats for nesting purposes. From table 4 it is apparent that the two restored habitats are both functioning to provide nesting habitat for each bird species, and the age, vegetative composition, and structure that is unique to each of these revegetated habitats does not appear to provide habitat that is consistently superior or inferior in quality. It should be noted, however, that the higher number of nesting attempts indicated by reproductive index scores and frequency distribution occurring in a given habitat do not necessarily equate with greater overall nesting success and could in fact be indicating that the area is a sink. This the case for "Old Reveg." which yielded higher frequency distribution and reproductive index scores but at the same time the lowest Mayfield nesting success and proportions of successful nests in 1998 .

When scores for both years across all measures of N_s are combined, it appears that "Old Reveg." provided slightly more valuable habitat for Song Sparrows and provided exactly the same nesting habitat value for Salt Marsh Yellowthroats as "New Reveg". However, when the data are disaggregated by years, it is apparent that there is great interannual fluctuation in habitat value for nesting birds. "New Reveg." provided better nesting habitat for Song Sparrows and Salt Marsh Yellowthroats in 1998. "Old Reveg." was a poorer substrate for nesting, rating an aggregate score of 8 and 9 for both species, respectively.

These scores also indicate that the overflow channel can provide valuable nesting habitat for both birds on the CCRS property, at least in some years. "Overflow channel" provided slightly better nesting habitat for Salt Marsh Yellowthroats than "Old Reveg." in 1998. In fact, all scores for the overflow channel are entirely driven by no nesting attempts there in 1997 so such scores could potentially increase with time as more habitat becomes available.

Table 4. Ranking of sites by year based on nesting outcomes, including frequency distribution, Mayfield nesting success probability, number of successful nests, and reproductive index (Van Horne).

Nesting success (N_s) Criteria	**Year**	**"Old Reveg."**		**"Overflow Channel"**		**"New Reveg."**	
		SOSP	**COYE**	**SOSP**	**COYE**	**SOSP**	**COYE**
Frequency Distribution	**1997**	2	1	3	3	1	2
	1998	1	1	2	3	2	2
Mayfield Success Probability	**1997**	1	1	3	3	2	2
	1998	3	3	1	1	2	2
Success or Failure	**1997**	1	1	3	3	2	2
	1998	3	3	2	1	1	2
Reproductive Index	**1997**	1	2	3	3	2	1
	1998	1	2	3	3	2	1
Total 1997		5***	5*	12***	12***	7**	7**
Total 1998		8***	9***	8*	8**	7**	7**
Total:		13**	14*	20***	20***	14*	17**

***= best aggregate nesting success**

****= intermediate aggregate nesting success** *****= least aggregate nesting success**

Objective 2.2 : Nest Mortality Factors and Nesting Success/failure

Objective 2.2 asks, Based on nest search data how are nesting Salt Marsh Yellowthroat and Song Sparrow populations at CCRS being affected by nest parasitism and predation, as a whole and by patch type?.

Parasitism by the Brown-headed Cowbird and predation as nest mortality factors were analyzed, incorporating both incidental observations and standardized methods as described by Van Horne (1983) to gain an understanding of these potential threats to reproductive success at CCRS. In addition, any mortality observed to have been caused by snakes, small mammals, foxes, cats, and other nest mortality factors were noted during process of nest searches. The order of observed frequency for all of these factors were later ranked, accordingly, within each site and among each species.

For 50% of the nests, no cause for nest failure could be identified. This table indicates that the order of severity of nest mortality factors observed in the process of nest searches during the 1997 and 1998 breeding seasons at CCRS are: (1) predation by snakes; (2) nest abandonment; (3) predation by small mammals; and (4) cowbird parasitism (figure 14).

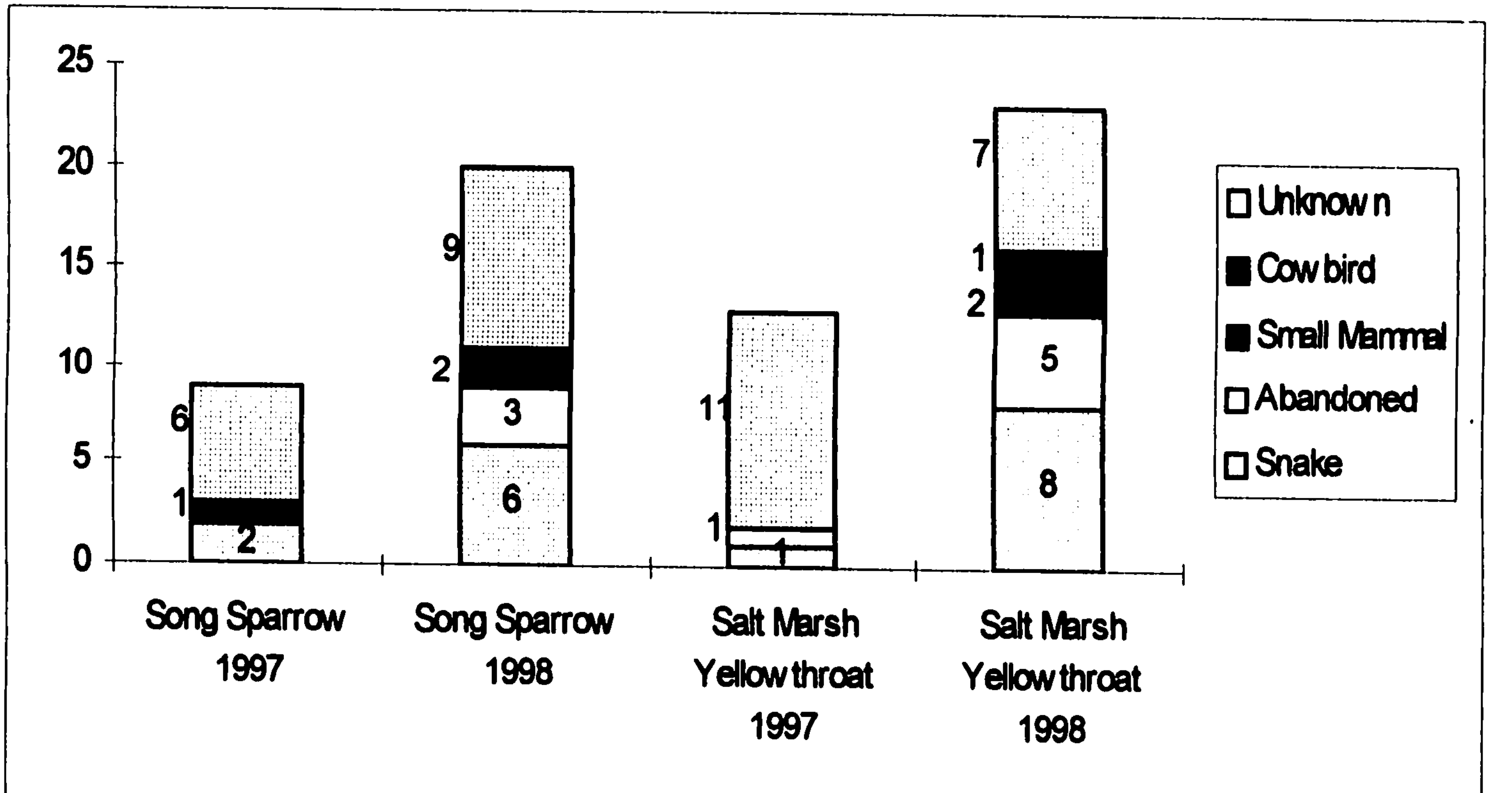

Figure 14. Leading nest failure causes documented during nest searches and territorial mapping, CCRS, 1997 and 1998. Figure 14 depicts the numbers of nests impacted by various factors of nest mortality. Figure displays data for nests with identifiable sources of failure only.

Focus 3: Habitat Composition and Management Strategies

A description of the vegetative habitat data analysis and results and how they answer objectives 3.1 and 3.2 is presented below. The evaluation of objectives 3.3 and 3.4, How are restored habitat vegetative characteristics and overflow channel management at CCRS affecting the population dynamics of these birds?, is addressed in the Discussion, based on all of the above analyses and results and in light of current and historic management practices.

Under focus question 3, objective 3.1 is to develop a description of habitat characteristics within each patch type. To accomplish this objective, the mean values of all vegetative habitat variables are summarized in tabular form by patch type, year and success or failure. The proportions of the most common plant support and cover species are graphed. Pie charts are used to depict the relative proportions of nest cover and support plants surrounding the nests encountered for each bird species and in each habitat patch that was monitored.

Objective 3.1: Average Nesting Habitat Characteristics

Table 5 lists the mean values for each of 24 habitat characteristics that were documented surrounding each nest. Because no nests were found in the overflow channel in 1997, only 1998 "Overflow Channel" values are listed in the table. Likewise, because all nests encountered in 1997 failed, the mean values for successful nesting habitat characteristics are only available for 1998. It is apparent from table 5 that less cover by brush and dead vegetation and lower proportion of bare ground surrounding micro and macrohabitats, greater foliage radius of the nearest woody vegetation, and greater percent cover by annual forbs (or herbaceous vegetation) are also associated with successful nests in all habitats in 1998.

The means characteristics showing trends from 1997 to 1998 were tested for significant variability by Student's T. The mean habitat characteristics that showed statistically significant variation by location were height of nearest woody vegetation, diameter breast height of nearest woody vegetation (NWV) and percent cover by annual forbs. The mean habitat characteristics that showed statistically significant variation by nesting success were distance to edge of microhabitat, distance to edge of macrohabitat, and dead vegetation. The mean habitat characteristics found to be statistically significant by ANOVAs of nesting success and location as the dependent variables are also indicated on table 5.

Table 5. Mean nesting habitat characteristic values for each patch type at CCRS, 1997 and 1998.

Location and year:	*Old Reveg. 1997 failed*	*Old. Reveg. 1998 failed*	*Old. Reveg. 1998 success*	*OF Channel 1998 failed*	*OF Channel 1998 success*	*New Reveg. 1997 failed*	*New Reveg. 1998 failed*	*New Reveg. 1998*
1. Nest height (cm)	41.1	57.6	32	45	54.3	59.6	45.2	45.6
2. Plant height (cm)	161.7	93.7	125	114.3	109.3	167.6	86.0	94.7
3. Micro size (m^2) •	13	152	35800	7	4	8	5	5
4. Ave ht. Micropatch (m) ♦	3	1.6	1.3	1.3	1.1	1	1.2	1.3
5. Dist. to edge micro (m) *	4	1.6	.3	1.4	.8	1	6.5	.8
6. Macrohabitat size (m^2)	812	806	20	1561.5	487.7	3138.9	3433.6	594.4
7. Ave ht. Macropatch(m)	4	1.8	1.5	1.5	1.5	3	1.7	2.6
8. Dist. to edge macro (m) *	20	2.5	1.5	5.4	2.9	10.52	5.4	5.0
9. Distance to forest (m) ♦	111.3	57	85	49.3	63.3	214.3	40.5	40
10. Dist. to restored habitat (m)	20.8	57	25	51.3	9.2	12.1	15.9	11.4
11. Dist. to overflow ch. (m)	27.6	14.9	10	20.3	21.1	15.1	23.9	25.0
12. Dist. to nearest woody vegetation (NWV) (m)	1.5	12.0	0	3.8	1.1	0	3.3	7.0
13. Radius NWV foliage (m) •	2	3.5	4.5	2.2	3.3	3	3.1	3.5
14. Height of NWV (m) ♦∇	7	2.8	1	2.59	3.5	4	2.8	2.9
15. DBH of NWV (cm) ♦∇	8.1	2.4	1	2	4	5.2	2.2	3.1
16. %cov. By trees	16.7	8	0	19	30	20.8	19.6	5
17. %cov. By grass ♦	16.7	10	25	0	.8	1.7	3	0
18. % cov. By ann. forb. ∇	66	85	95	69	77.2	33.2	62	95
19. % cov. By brush ♦	22	13.8	0	35.7	17.5	82.4	47	15
20. % cov. by bare ground	28.1	23	15	21	18.3	49.8	15	8
21. % cov. By dead forb *	60.4	27.7	20	20.2	18	49.3	18.9	7
22. % nest concealment, 1m	83.3	97.6	100	98.9	74.2	60.7	94.4	74
23. % nest concealment, above	93.4	77	90	71.9	57.8	81.7	74	86
24. % nest concealment, low •	72.3	98	100	77	91.7	39.4	94.5	94

Statistically significant variables: * = Student's T by success/non-success; ∇ = Student's T by location; • = ANOVA by success/non-success; ♦ = ANOVA by location.

Leading Nest Support and Cover Plants

For this thesis nest support plants are defined as species of vegetation which serve as nesting substrate and/ or structural support for each nest encountered. Nest cover plants are defined as species of vegetation which function as protective cover for each of the nests encountered.

A. Leading Nest Support Plants for each Bird Species

Across all habitat patches the proportion of Salt Marsh Yellowthroat nests were highest in Pepper Grass while a higher proportion of Song Sparrow nests were found in California Native Blackberry (see figure 16). The nests of both species were found in similar proportions in California Goldenrod, Mugwort, California Golden Aster, and Coyote Brush. Salt Marsh Yellowthroat nests were found in slightly higher proportions in Golden Aster than Song Sparrow nests. Some Song Sparrow nests were also supported by California Elderberry and Rosilla spp..

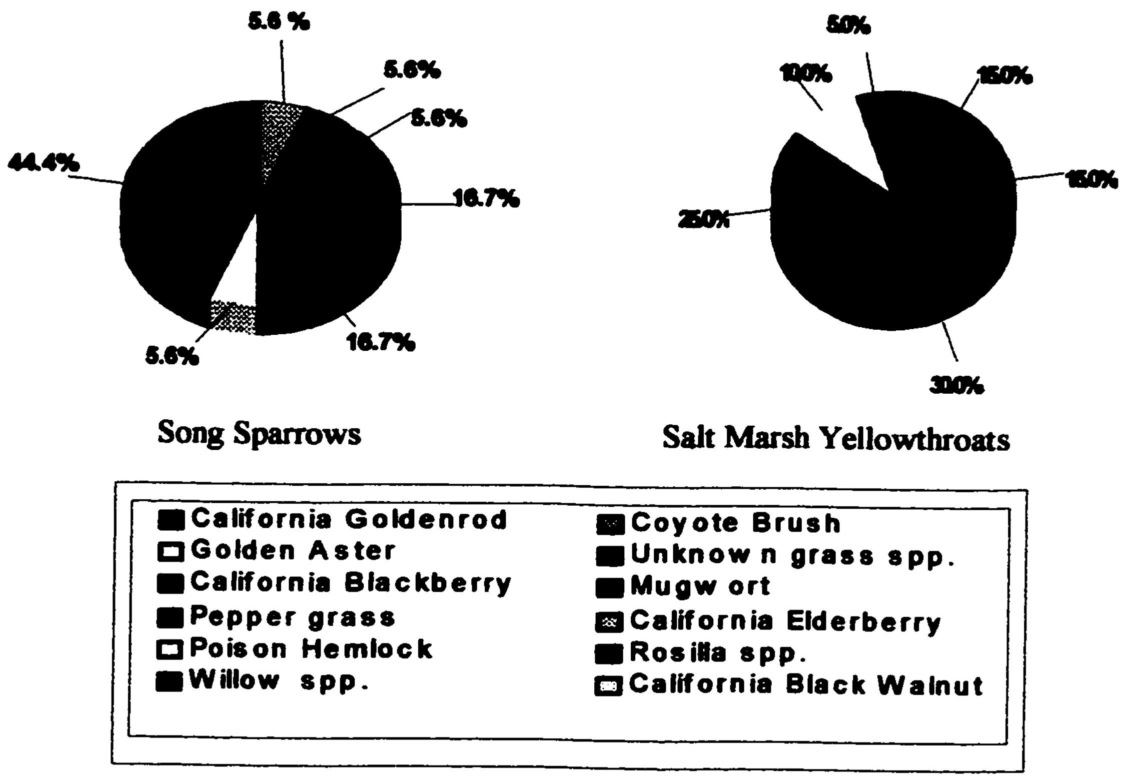

Figure 15. Relative proportions of leading nest support plant species for Song Sparrows and Salt Marsh Yellowthroats across all habitats at CCRS, 1997-1998.

B. Leading Nest Support Plant Species for each Location

Throughout the three habitat patches, Pepper Grass, Goldenrod, Coyote Brush, Blackberry and Mugwort were the most important nest support species, with proportions of each varying from site to site and year to year.

In 1997 and 1998, the highest proportion of "Old Reveg." nests were found in invasive Pepper Grass (see figure 16). A decrease in habitat diversity appeared to have occurred in "Old Reveg." from 1997 to 1998, as unknown grass species, Golden Aster, and Goldenrod were crowded out by Pepper Grass and Mugwort. In "New Reveg.", the dominant species of vegetation where nests were found in "New Reveg." changed from one year to the next. In 1997 the highest proportion of "New Reveg." nests were found in California Goldenrod and Pepper Grass. In 1998, the highest proportions of "New Reveg." nests were found in Blackberry and Coyote Brush. The highest proportions of the 1998 overflow channel nests were found in Goldenrod and the variability of nest cover species was much lower.

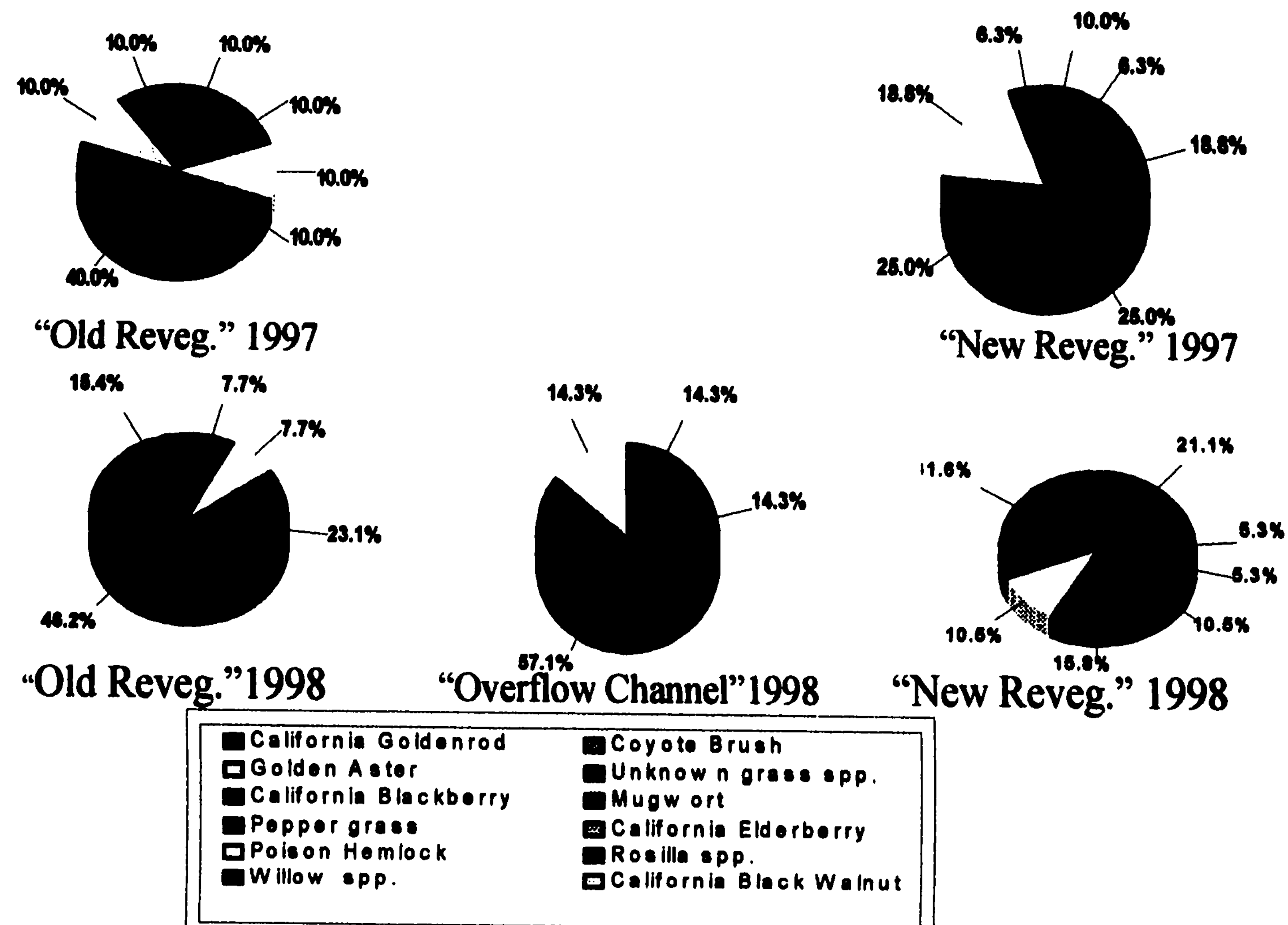

Figure 16. Proportions of leading nest support plant species in "Old Reveg.", "New Reveg."and "Overflow Channel", CCRS, 1997 and 1998.

C. Leading Nest Cover Plant Species for each Bird Species

Most Song Sparrow nests were covered by Pepper Grass, California Goldenrod, Golden Aster, and Mugwort They were also covered by Willow, Blackberry, Coyote Brush (see figure 17). Most Salt Marsh Yellowthroat nests were covered by California Blackberry, Coyote Brush, Pepper Grass and California Goldenrod. They were also covered by Poison Hemlock, Rosilla spp., Golden Aster and Mugwort.

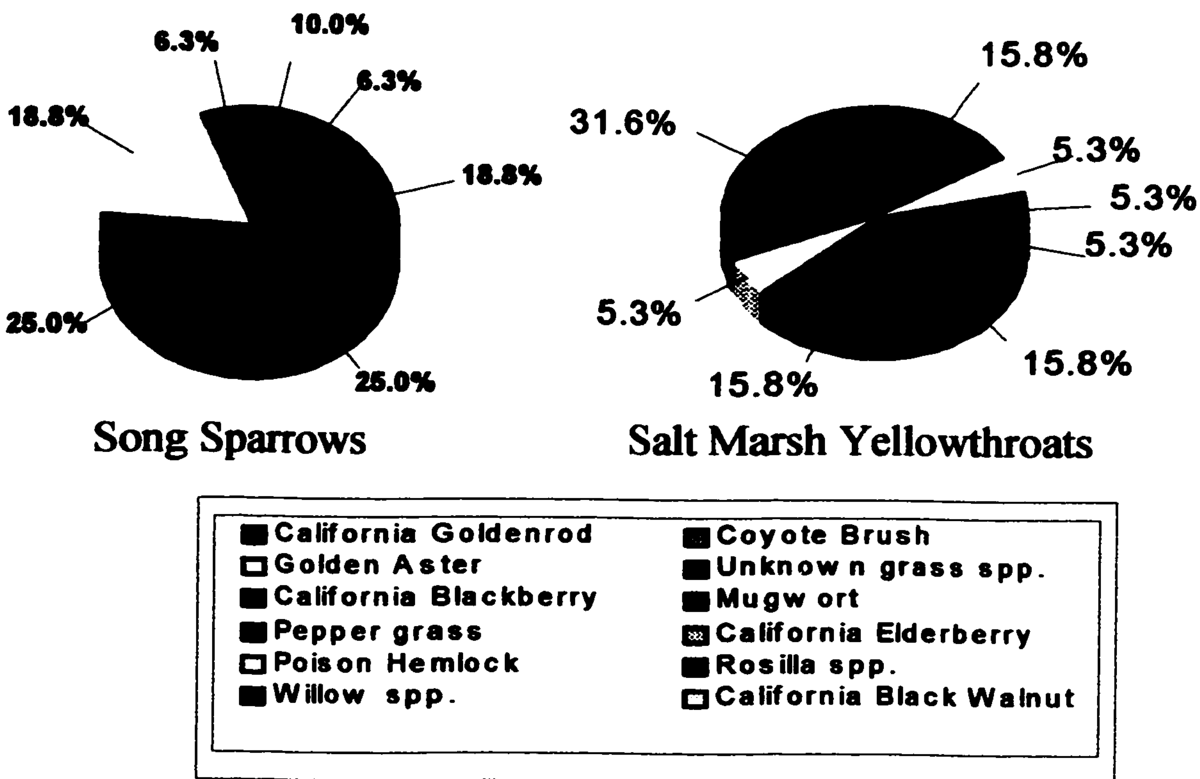

Figure 17. Proportions of leading nest cover plant species for Song Sparrows and Salt Marsh Yellowthroats, 1997-1998.

D. Leading Nest Cover Plant Species for each Location

In 1997 many nests found in both habitat patches were covered by Coyote brush, although Pepper Grass was the leading nest cover species in "Old Reveg." (see figure 18). Willow and Golden Aster were also nest cover species in both habitat patches. "New Reveg." nests were also covered by California Goldenrod and California Elderberry.

The leading nest cover species in "Old Reveg." in 1998 was Pepper Grass. There was a decrease in the proportion of California Goldenrod in "Old Reveg." from 1997 to 1998. The nest cover species that was found in the overflow channel in 1998 was remarkably diverse for only one year of growth. Blackberry, Coyote Brush, California Goldenrod, and Golden Aster were the leading nest cover species encountered there in 1998. The array of nest cover species in the overflow channel was also more complex than the nest support species that were encountered there. California Goldenrod became the leading nest cover species occurring in "New Reveg." in 1998, while the proportion of Coyote Brush declined somewhat and the diversity of plant species became less complex than it was in 1997.

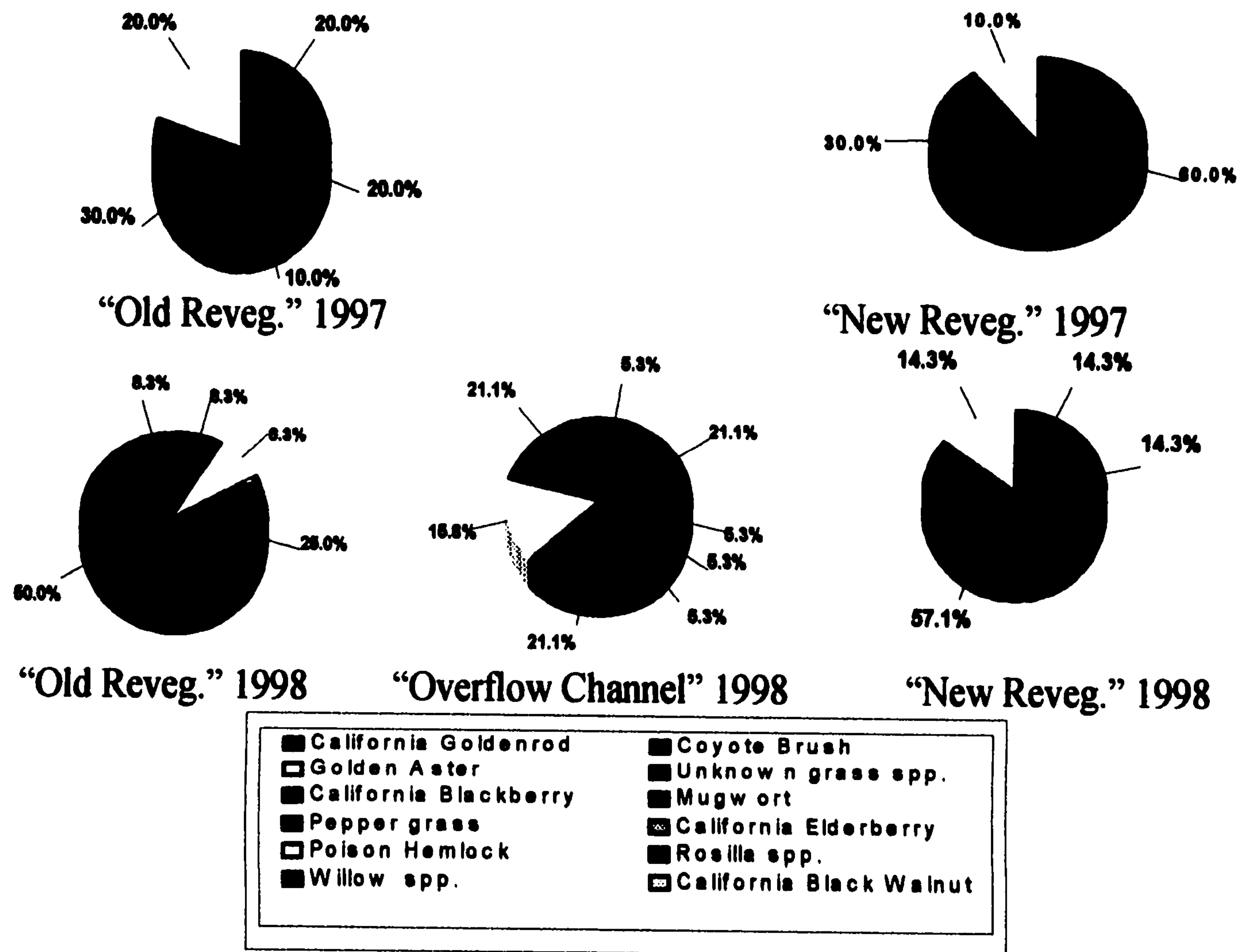

Figure 18. Proportions of leading nest cover plant species in "Old Reveg.", "New Reveg."and "Overflow Channel", CCRS, 1997 and 1998.

Objective 3.2 : Correlation of Nest Success/failure with Specific Habitat Characteristics

Leading proportions of nest support plant species for successful and non-successful nests

From figures 19 and 20 it is clear that a higher proportion of failed nests were located in Pepper Grass than any other plant species. It is also evident that most successful nests were located in California Goldenrod.

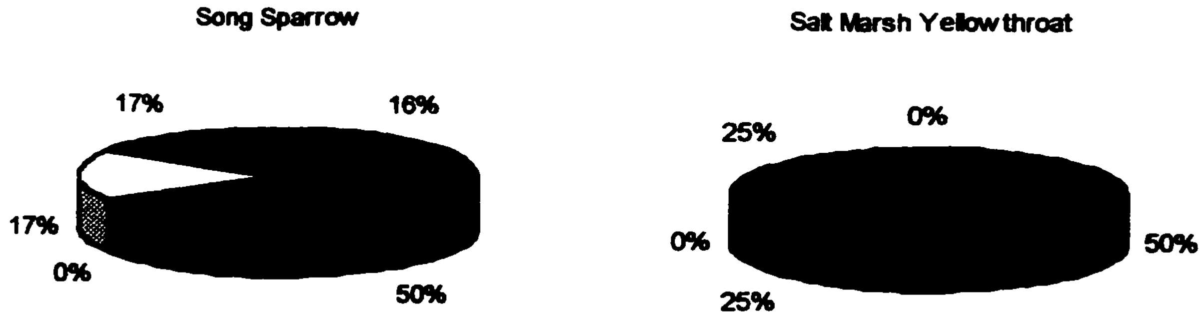

Figure 19. Proportion of successful nests found in nesting substrate at CCRS, 1997-1998.

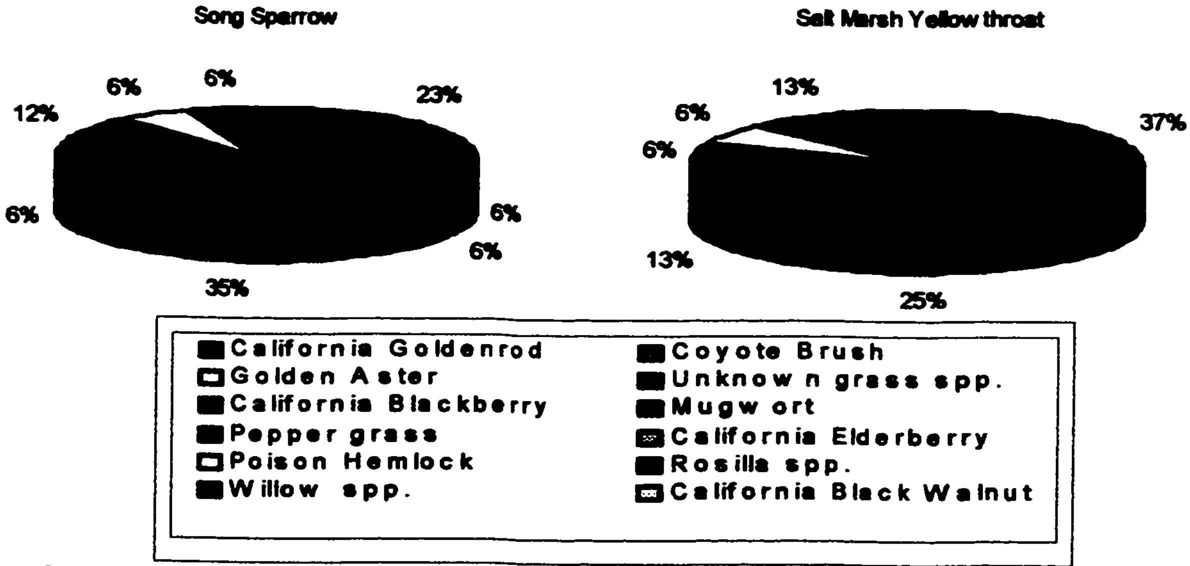

Figure 20. Proportion of failed nests found in nesting substrate at CCRS, 1997-1998.

The proportion of successful and failed nests for each species is depicted in table 6 based on all nests found within a given substrate. Table 6 indicates that the biggest drains on Song Sparrow nesting were Pepper Grass and California Blackberry. Sixty percent of the 10 nests attempted in California Blackberry and 80% of the 5 nests attempted in Pepper Grass were failed Song Sparrow nests. The biggest drains on nesting for Salt Marsh Yellowthroats were Pepper Grass, Coyote Brush and Mugwort. Eighty percent of the 10 nests attempted in Pepper Grass, 71% of the 7 nests attempted in Coyote Brush, and 75% of the 4 Salt Marsh Yellowthroat nests attempted in Mugwort were failed.

The highest proportion of successful nesting for Song Sparrows took place in Coyote Brush and California Goldenrod: 66% of the 6 Song Sparrow nests found in Coyote Brush and 66% of the 3 Song Sparrow nests found in California Goldenrod were successful. The highest proportion of successful nesting for Salt Marsh Yellowthroats took place in California Goldenrod. Sixty-six percent of the 9 Salt Marsh Yellowthroat nests attempted in California Goldenrod were successful.

Table 6. Proportions of failed and successful nests found in nesting substrate for Song Sparrows and Salt Marsh Yellowthroats at CCRS, 1997-1998.

Plant Species	# nests attempted	Song Sparrow		# nests attempted	Salt Marsh Yellowthroat	
		% Failed	% Successful		% Failed	% Successful
Pepper Grass	5	80	20	10	80	20
Mugwort	2	100	0	4	75	25
California Goldenrod	3	33	66	9	33	66
California Blackberry	10	60	40	1	100	0
Golden Aster	1	100	0	2	50	50
Coyote Brush	6	33	66	7	71	29
Salix sp.	1	100	0	0	N/A	N/A
Poison Hemlock	0	N/A	N/A	1	100	0
Unknown grass	1	100	0	0	N/A	N/A
California Walnut	0	N/A	N/A	1	100	0
Rosilla sp.	1	100	0	0	N/A	N/A

A. ANOVA and Student's T of Habitat Characteristics and Location

The ANOVA conducted for the 26 habitat characteristics documented for each nest on the property indicates that most of the characteristics exist in each location due to chance alone (see Appendix C). Percent cover by grass and shrubs within a 10 meter radius of the nest; average microhabitat height; height of nearest woody vegetation; and diameter breast height (DBH) of the nearest woody vegetation were all indicated to have varied significantly. Human manipulation of these habitat characteristics may have a bearing on the extent or rate of variation in vegetation among the three habitat patch types at CCRS. This coincides with the trends in table 5 which show that less cover by brush, greater foliage radius of the nearest woody vegetation, and greater percent cover by annual forbs (or herbaceous vegetation) are associated with successful nests in all habitats in 1998.

Student's two sample, two-tailed T-tests were conducted to determine exactly which of these factors has changed significantly at CCRS from 1997 to 1998 and the results are summarized in table 6. Four out of the six habitat characteristics tested proved to have significantly different means when compared by year within each of the three habitat patch types. The percent shrub and herb layer, height of nearest woody vegetation, and DBH of nearest woody vegetation, all proved to have changed significantly from 1997 to 1998. Such changes in these characteristics among the three patch types may have had a bearing on the increase in overall nesting success in 1998.

Table 7 . Summarized results of Student's 2 tailed, 2 sample T-tests for each vegetative habitat characteristic found to vary significantly in the ANOVAs of habitat characteristics and location.

Annual growth or change in vegetation cover, type, or height. Ho = there is no significant difference between the 2 sample means

% grass layer	% herb layer	% shrub layer	Mean height of micropatch (m)	Height of nearest woody vegetation (m)	DBH of NWV (cm)
0.19 Accept H_0	**0.028* Reject H_0**	**0.028* Reject H_0**	0.15 Accept H_0	**0.005* Reject H_0**	**0.00004* Reject H_0**

B. ANOVA and Student's T of habitat characteristics and nesting success/ non-success

The ANOVA conducted for the 26 habitat characteristics documented for each nest on the property indicates that most of the characteristics are not associated with nesting success or non-success (see Appendix D). Only year, percent nest concealment below the nest, foliage radius of nearest woody vegetation, and size of the micropatch were indicated by the ANOVA to have significant variation when success/ non-success is the dependent variable.

Student's two sample, two-tailed T-tests were conducted to determine exactly which of these factors corresponded to nesting success or non-success at CCRS from 1997 to 1998. None of the above vegetative habitat characteristics that were found significantly variable by the ANOVA was indicated to vary significantly by successful and non-successful nests when a Student's T was conducted.

Student's T did, however, indicate significant variation among the means of variables that showed trends in Table 5. Sample means of successful and non-successful nest percent cover by dead vegetation, distance to the edge of the macrohabitat, and distance to the edge of the microhabitat were all indicated to vary significantly.

Table 8 . Summarized results of Student's 2 tailed, 2 sample T-tests for each vegetative habitat characteristic found to vary significantly in the ANOVAs of habitat characteristics and nesting success.

Correlation between nesting success and year, percent vegetative cover, nearest woody vegetation foliage radius, size of the microhabitat. Ho = there is no significant difference between the 2 sample means

Year	%cover herb layer	% cover bare ground	% cover dead forb	% cover brush	Microhabitat size (m. sq.)	NWV foliage radius. (m)	Distance to edge of microhabitat	Distance to edge of macrohabitat
0.002* **Reject H_o***	0.89 Accept H_o	0.35 Accept H_o	**0.005*** **Reject H_o***	0.60 Accept H_o	0.33 Accept H_o	0.14 Accept H_o	**0.039*** **Reject H_o**	**0.039*** **Reject H_o**

Discussion

Evaluation of habitat for nesting potential

Objectives 3.3-3.4, in summary, call for the description and evaluation of the management of the restored habitat patches and the overflow channel. The considerations that were made in order to fully address these two objectives include:

(1) looking for declines in the three population components (adult recaptured males and females, and juveniles) relative to the timing of mowing and subsequent flooding of the overflow channel during the breeding season;

(2) evaluating the results of nesting frequency, nesting success, reproductive success, and nest mortality factors within each site for each species individually, and together, as a guild (riparian shrub habitat species); and

(3) evaluating the results of quantitative analysis of habitat composition and structure relative to the current nesting habitat potential for each patch type.

These considerations were applied to the results which are discussed in detail below.

By all accounts in the population dynamics evaluation the nesting success has effected a Salt Marsh Yellowthroat population decrease since the mowing of the overflow channel in 1996. This phenomenon is first illustrated in Figure 2 which shows that the numbers of juveniles and adults of both populations declined in the year following the mowing of the overflow channel. From figure 7 it can be concluded that even at a maximum potential, Salt Marsh Yellowthroats never incur sizable population growth in the years that were documented and that neither species is anywhere near the maximum potential of population size. This deduction is again illustrated in figures 8 and 9, which depict low fledgling success for both species coinciding with the period after the overflow channel was mowed, as the replacement ratios and net replacement for both species decline dramatically. As of 1998, neither population was depicted at or above the replacement level. It is most likely true therefore that the mowing of the overflow channel has caused much immediate, short term, and possibly long term impacts on both breeding populations. The short term improvement in Mayfield nesting success probability from 0 to 7% from 1997 to 1998 may be indicative that the populations have the potential to bounce back from overflow channel management and long-term impacts will be diminished. More long-term observation is still needed, however, to support this deduction.

In general, nest predation factors affected the nests of both species in an order of severity that is similar to factors which occur in natural riparian habitat for these species (Best and Stauffer, 1980). However, the comparatively low proportion of Salt Marsh Yellowthroat nests that were observed to have been parasitized at CCRS is inconsistent with a study by Martin (1989), who found that Cowbird parasitism was the leading cause nest of failure in a study of CommonYellowthroats. The relative lack of Cowbird parasitism despite a consistent Cowbird presence may indicate that (1) Cowbird eggs were removed by these species but such activity was never detected by the observer; (2) that neither of these two species were leading candidates for parasitism by Cowbirds on the property, and therefore did not suffer the brunt of the parasitic behavior by them; (3) the number of parasitized nests were under-represented because those nests that had 'unknown' or 'abandoned' outcomes had been parasitized at one time prior to abandonment and depredation of the rejected clutch or (4) a combination of any or all of these scenarios.

The increase in all reproductive index rankings in 1998 may be due in part to the improvement in the ability of the observer to document nesting and breeding bird behavior, as well as the increased intensity and duration of both nest search and territorial mapping methods from one year to the next. However, the marked increase in the overflow channel rankings from 1997 to 1998 compared to the relatively smaller increase in values for both species in "Old reveg." and "New Reveg." would indicate that another factor, such as vegetative growth has improved the conditions for both species in the overflow channel.

It is important to note that because the Van Horne method of ranking reproductive success is indicative of breeding effort and nesting attempts, such information should be viewed in conjunction with nesting success in order to determine whether a habitat patch is functioning as a source or a sink. Despite the fact that "Old Reveg." out-ranked the other two habitat patch types according to Van Horne's reproductive index scale, when reproductive index and nesting success criteria are combined it becomes apparent that the area is functioning as a sink on the property. This was especially true in 1998, when the highest proportion of birds attempted to nest in "Old Reveg." but the lowest proportion of successful nests were documented there per hectare.

Based on the results of this thesis, both the structure and the respective ages of the two restored habitat patch types at CCRS are potential contributing factors to the nesting habitat suitability, preference, or likelihood of nesting success for each of the two species studied. Both of the younger "Overflow channel" and "New Reveg." habitats which both have an understory out-performed "Old Reveg." in terms of nesting success in 1998 which was not initially planted with an understory component. After the plan to restore the "Old Reveg." habitat patch was implemented, there was some concern that the lack of an understory in "Old Reveg." would result in diminished habitat value. The results of this thesis indicate that the initial lack of understory cover by native shrubs, grasses and herbs has indeed caused disparity between overall nesting success or nesting habitat suitability among the three habitat patch types. Pepper Grass, an invasive, non-native species that undergoes major die-back in the late summer months has tended to out-compete natural recruitment of native understory vegetation in "Old Reveg.". In 1998, Pepper grass was documented as the leading understory vegetative component in "Old Reveg" while Mayfield nesting success scores were the lowest there among all habitat patches that same year. Because Pepper Grass has a tendency to lean over as it grows taller it may have caused the nests in "Old Reveg." to become lowered before fledging could occur, resulting in an increased opportunity for nest depredation there in 1998.

The relative age within a habitat patch may have also contributed to nesting success outcomes. It was observed anecdotally and evident through the data collected in this thesis that the Coyote Brush in "New Reveg." grew too large to be able to function well as nesting substrate in "New Reveg." in 1998. As the trunk and branches of the Coyote Brush grew in size, the amount of available low nest cover by the leaves diminished greatly, especially for Salt Marsh Yellowthroat nests which were encountered more often than Song Sparrow nests in Coyote Brush.. Both the ANOVA indicating that greater percentage low nest concealment is correlated with successful nests and the information in table 6 indicating that Salt Marsh Yellowthroats had a high proportion of failed nests in Coyote Brush support the premise that older Coyote Brush does not provide viable nesting substrate for Salt Marsh Yellowthroats.

There is strong evidence provided by all results that vegetative characteristics that have been manipulated by overflow channel management have an influence on nesting habitat suitability and/or preferences of Song Sparrows and Salt Marsh Yellowthroats at CCRS. When the nesting habitat once available in the overflow channel was mowed, the overall nesting success and population dynamics of both species were directly affected. All graphs in the population dynamics section of this thesis provide evidence that both Song Sparrows and Salt Marsh Yellowthroats were forced to make use of the less optimal habitat in the two restored habitat patches in the year after the overflow channel was mowed and the results were disastrous.

All nesting outcomes are indicative of the key role that the overflow channel and transitional habitats play in the nesting success of these two bird species. From the ANOVAs and Student's Ts comparing vegetative habitat characteristics by year for each location it can be inferred that the vegetative growth from year to year is very dynamic on the property and there is much potential for change in year to year nesting habitat suitability. After only one year of growth, the overflow channel yielded a higher overall Mayfield nesting success probability than the two other habitats exhibited in either year. Figure 12 indicates that nests constructed in the overflow channel had the greatest potential for nesting success, from nest-building to fledgling, for both species during the

1998 breeding season. The fact that the overflow channel yielded relatively high values of Mayfield nesting success probabilities is quite remarkable. After one year of natural vegetative recruitment and growth the habitat that had regrown in the overflow channel provided enough cover and habitat to promote higher fledgling productivity than the more established vegetative rehabilitation sites had provided. The abilities of the observer to document the success of each nest may have had some bearing on the increase in all Mayfield probabilities over time but other factors, such as vegetative growth or chance, may have influenced these figures as well and cannot be ruled out.

All of the outcomes of this thesis are indicative of a possible explanation of why and how Salt Marsh Yellowthroats came to be using the overflow channel and upland riparian habitat at CCRS, a habitat that they do not typically use for nesting. Because the overflow channel floods periodically, it mimics a naturally occurring wetland for a portion of the year. In 1998, the overflow channel was flooded until the beginning of the nesting season. It may be that since these birds have evolved to nest in marshy habitat where there is typically an abundance of water (to such an extent that their nests are often found floating) they do not expend their energy in search of habitat with a developed overstory but rather for a habitat that has a presence of fresh water. Since, in this respect, these birds are well adapted to a transitional, "underdeveloped", habitat if there is at least some standing water present, for even a short time period annually, it follows that they would make use of the overflow channel for nesting.

In fact, as illustrated by this thesis the overflow channel is the superior option for nesting Salt Marsh Yellowthroats on the CCRS property because its tendency to flood and to be lacking a protective overstory, would serve to deter the presence of snakes, the leading nest predator documented in this thesis. Snakes might easily become prey items in an open area such as the overflow channel or may drown if it is flooded and so would not have a strong propensity to exist there as often as they would in the other two habitat patches.

If the overflow channel is mowed too frequently, the lack of vegetative cover from predators and impact on available nesting habitat will only perpetuate poor nesting success at CCRS and contribute to local population decline for Salt Marsh Yellowthroats and Song Sparrows. Because, the birds were able to nest in the overflow channel after only one year of growth, it is critical that this area be maintained for nesting habitat suitability and that the restored habitat be managed to ensure that there is ample supply of nest cover and substrate for Salt Marsh Yellowthroats and Song Sparrows over the long run. Such management strategies would include native plant substrate propagation and invasive species control as defined by the recommendations in the Conclusion.

Methodological Limitations

This thesis analyzed only 2 years of nest search data, supplying only a point of information. Due to time constraints data sample replication for this thesis was not as rigorous as is needed to be to ensure statistically reliable results. Therefore, the conclusions that can be drawn from these data are not as statistically sound as they might have been given three or more additional years of replication. For focus question 1 it must be noted that although it is possible to determine whether year-to-year population changes are significant, it was not possible with a limited study of this sort to determine whether these changes are part of long-term trends or if they simply reflect natural variability. Moreover, the broader implications of population dynamics and net seasonal fecundity could not be extrapolated from such a short time period. No implications for the status of individual species as a whole in the Bay area could be determined since the time frame of study was limited and only covered a small portion of their habitat. Also, no evaluation was made concerning the impacts of adjacent land use factors, including the impacts that will undoubtedly occur once adjacent land is developed.

The impact of two preexisting conditions that exist on the CCRS property require discussion: 1- as illustrated in the map of the study sites (Figure 1), Coyote Creek is closest to "Old Reveg." and most distant from "New Reveg.", with "Overflow Channel" falling between the two revegetated habitats; 2- the overflow channel floods periodically and was flooded at the beginning of both breeding seasons in 1997 and 1998. The correlation between nesting frequency and spatial or temporal proximity to water could be a potentially confounding factor when drawing conclusions about nesting success and the habitat characteristics (i.e. age, habitat composition, etc.) that are unique for each site. It is therefore necessary to be cognizant of the fact that any effects caused by spatial and temporal proximity of the nests to water may have had additional bearing on the outcomes for this thesis.

Conclusions

The evaluation of population dynamics and nesting outcomes clearly establishes the current role of the nesting habitat at CCRS as a sink to local population numbers, especially in the years subsequent to the mowing of the overflow channel. Although the wildlife-monitoring program at CCRS was discontinued in 1998, the San Francisco Bay Bird Observatory (SFBBO) has taken over the role of monitoring the avian inhabitants of Coyote Creek on the SCVWD property.

Evidence has been provided that future management of the property by SCVWD must be altered if the habitat there is to function ultimately as a source for both species in the South San Francisco Bay. Recommendations for the features that can be managed within the study area, namely the structure and function of the overflow channel and restored habitat composition, are described in the following sub-section.

Recommendations

From the results of this thesis, it is clear that the mowing of the overflow channel has had some impact on the immediate fledgling productivity and nest mortality in the channel and the adjacent sites. The amount of habitat that should be left, in order to minimize impacts on populations when the overflow channel is mowed, was made based on estimates of the density/hectare of nesting Yellowthroats and Song sparrows at CCRS in the years prior to the mowing of the overflow channel: 4.59 nests/ha. From this estimate it can be recommended that a buffer of at least 0.21 hectares should be left surrounding every known nest location in order to lessen the impact on the nesting birds at the time of mowing. Additionally, a portion of the overflow channel deemed viable by the SCVWD should be left untouched during the time of mowing. The portion that is set aside could alternate from one mowing to the next. This management method would help to maintain a patch of intermediate stage plant growth in at least part of the overflow channel at all times. From this thesis, it appears that such intermediate plant growth is the optimum nesting habitat for these species and would promote positive nesting outcomes at CCRS.

It also is recommended that the interval between mowing last long enough for a clear population rebound to occur for both species. A population rebound includes both returning adults and pre-mowing fledgling productivity. Since the fledgling productivity observed during this study did not fully rebound, the number of remaining years required for such a rebound to take place is determined by using the following equation.

Equation 3:

$$\mathbf{T} = \frac{(\mathbf{F}_{max})}{(\mathbf{F}_{1998})}$$

whereby $\mathbf{F}_{max}$ is the maximum fledgling:adult ratio that was observed to occur prior to overflow channel management, $\mathbf{F}_{1998}$ fledgling productivity that was observed in 1998, incidentally the lowest fledgling:adult ratios documented since the mowing of the overflow channel. Using the 1998 baseline replacement ratio for Song Sparrows (0.35), it was estimated that 19 years will pass (after 1998) before to the maximum pre-overflow channel management fledgling:adult replacement ratio (6.73) is achieved. Using the 1998 baseline replacement ratio for Salt Marsh Yellowthroats (0.13), it was estimated that 17 years will pass (after 1998) before the maximum pre-overflow channel management fledgling:adult replacement ratio (2.16) is achieved. It is therefore recommended that the nesting habitat for both of these species be protected, enhanced with more protective and less invasive native nest cover and substrate plant species (see below), and monitored until these populations experience a full rebound or 20 years (subsequent to 1998), if a full rebound is not observed to occur within that time frame.

Recommendations for improved vegetative habitat components are given based on the information in Table 6 and the results of the ANOVAs of successful habitat components. As mentioned in the discussion, the invasive plant species Pepper Grass may have out-competed native species and may be undermining further possibility for successful nesting later in the breeding season. It is evident from Table 6 and figures 19 and 20 that California Goldenrod has provided a superior nesting substrate for both species. It is therefore recommended that the Pepper Grass be removed, on an experimental basis, at a rate that would not diminish the area of the available nesting habitat for these species, and be ultimately replaced by the native plants that were observed to yield higher proportions of successful nests. It appears that California Goldenrod is the superior choice as an alternative to Pepper Grass and should be propagated, on an experimental basis, wherever necessary on the property.

In one year of growth of older Coyote Brush it was observed that the foliage on the outer surface of the bush had grown too dense for any light to penetrate, thus preventing leaf growth the on lower branches of the plants. It is therefore recommended that Coyote Brush be thinned in "New Reveg." on an experimental basis to give a clear idea of how the structure and age of this plant might influence nesting success for both birds. In general, it is recommended that there be more experimentation on what specifically would improve restored habitat from sinks to viable habitat.

The final recommendation is that the predatory habits of snakes and their impact on nesting success of Salt Marsh Yellowthroats and Song Sparrows should be studied in depth on the property.

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Appendix A - Species list of riparian vegetation planted at Coyote Creek

The following is a general list of plants that were planted at each of the three restoration sites, in varying proportions for each location.

Trees	Shrubs	Herbaceous
Box Elder (*Acer negundo*)	Sagebrush (*Artemisia spp.*)	Mugwort (*Artemesia douglasiana*)
Black Walnut (*Juglans* spp.)	Coyote Brush (*Baccharus pilularis*)	Western Aster (*Aster californicus*)
Sycamore (*Platanus racemosa*)	Mule Fat (*Baccharus* spp.)	Douglas Baccharis (*Baccharis douglassii*)
Fremont Cottonwood (*Populus fremontii*)	Snowberry (*Symphoricarpos* spp.)	Beardless Wildrye (*Elymus glaucus)*
Coast Live Oak (*Quercus agrifolia*)	Hollyleaf Cherry (*Rhamnus crocea*)	Western Goldenrod (*Solidago occidentalis*)
Valley Oak (*Q. lobata*)	California Rose (*Rosa californica*)	
Red Willow (*Salix spp.*)	Blackberry (*Rubus vitifolius*)	
California Bay (*Umbellularia californica*)	Arroyo Willow (*Salix lasiolepis*)	
Yellow Willow (*Salix lutea.*)	Elderberry (*Sambucus mexicana*)	

Appendix B - Descriptions of variables measured in vegetative assessment

(Adapted from : H.Spautz, April, 1997. Vegetation analysis - Common Yellowthroat at Kern River Preserve.)

The following is a description of each of the variables measured:

1. Nest height: from the ground to the top rim of the nest, to the nearest cm.
2. Plant height: the plant to which the nest is primarily attached, (or if attached to several, the tallest plant) measured to its highest point to the nearest cm.
3. Nest support species: a list of all species to which nest is attached, including dead grass or forbs (these are often not named by species but called "dead grass" or "dead forbs"); usually not more than 3 species.
4. Nest cover species: a list of all species that provide concealment to the nest even if the nest is not attached to them, including dead plants.

Nest concealment measures: here a white paper circle representing the approximate diameter of a nest is used. The approximate proportion of the nest that is concealed is recorded (if you cannot see the circle at all, record "100%") estimates are made from directly above the nest at standing height, and from each of the 4 directions, each from a standing position at 1 m from nest (to simulate the view of a cowbird or an avian predator) and from a crouched position 0.5 m from the nest (to simulate a mammalian predator's view).

5. % above: look at the nest from directly above, with the circle laid flat on the nest
6. standing/1m: place the circle vertically inside the nest and view it from a standing position 1 meter away, from each of the 4 directions. An average value is calculated (percentage).

7. low/0.5m: circle vertical as above, viewed from a crouching position, head near the ground, from 0.5 m away. Average percentage value calculated.
8. Canopy closure: this is estimated using a densiometer.

(a) all cardinal directions, 5 meters from the nest; and

(b) at the nest immediately to the North and immediately to the South

Percent cover measures: estimate the overall percentage to nearest 5%, of each vegetation category within the entire 5 m radius circle. These values can be categorized later (I used 0%=0, 1-10%=1, 11-49%=2, 50%==3). The percentages of all components can add up to more than 100% because you have a canopy and understory. When the two dominant species are required, their presence overall are recorded (e.g. grass 50%, alkali rye 25% [of total, while it is 50% of the grass], *B. diandrus* 25%).

9. % tree: imagine looking down or up vertically at the circle and include the entire area covered by the canopy.
10. % grass cover: plus % of two most common species; includes sedges and rushes (unless tule-sized); may include dead material.
11. % ann.forb: as above
12. % live brush cover: as above. This includes mulefat, blackberry, or any other woody shrub (not mugwort)
13. % bare ground: includes area covered by leaf litter and duff
14. % dead forb: no need to include species. Will mainly include previous year's growth.
15. Nest-centered height profile:

This is a measurement of the presence of vegetation within each of the vertical 0.5 meter intervals. Use the 5m radius ropes and a pole at least 3 m long, marked to the nearest 10 cm for the first meter, then at each 0.5 meter). For each direction, a point is measured at the nest (just at its edge, not through the center), and at each of the 1-meter intervals up to 5 meters. Imagine a cylinder of diameter 10 cm, centered on the pole. If at least one leaf or stem lies within this cylinder, it is counted as a hit. The vertical intervals are each 0.5 meter up to 3 meters, then whole meters up to 7 meters, then 7+ meters. Each square is marked with an x (not a number of hits). Understory - dead stems are included because they are important to Yellowthroats; dead tree branches are not included. To analyze data, count the number of hits in each vertical interval, totaling 21 possible. The center point, at the nest, is averaged (two or more hits = single hit).

Appendix C – ANOVA of Vegetative Characteristics with Location as the Dependent Variable

H_0 = the observed differences in habitat variables among "Old Reveg.", "Overflow Channel", and "New Reveg." vary by chance alone.

Response Variable	**Term**	**Source of Variation**	**Df**	**SS**	**MS**	**F-Ratio**	**Prob Level Power**	**(Alpha=0 .05)**
1. Success(1)/ Failure (0)	Location	Between Groups	2	0.16	0.08	0.59	0.56 Accept H_o	0.14
2. Year	Location	Between Groups	2	3.65	1.83	10.65	**0.0001* Reject H_o**	0.99
3. Nest Height	Location	Between Groups	2	326.52	163.26	0.30	0.74 Accept H_o	0.10
4. Plant Height	Location	Between Groups	2	5592.33	2796.17	0.75	0.48 Accept H_o	0.17
5. Micro size (m^2)	Location	Between Groups	2	6.83E+07	3.42E+07	1.75	0.18 Accept H_o	0.35
6. Average ht micro (m)	Location	Between Groups	2	11.47	5.74	4.32	**0.017* Reject H_o**	0.73
7. Dist. to edge of micro (m)	Location	Between Groups	2	43.82	21.91	0.45	0.64 Accept H_o	0.12
8. Macro size (m^2)	Location	Between Groups	1	4.32E+07	2.16E+07	1.16	0.32 Accept H_o	0.24
9. Average ht macro (m)	Location	Between Groups	1	31.62	15.81	2.22	0.12 Accept H_o	0.44
10. Dist. to edge of macro (m)	Location	Between Groups	1	597.54	298.77	0.82	0.45 Accept H_o	0.18
11. Distance to forest (m)	Location	Between Groups	2	4.98E+04	2.49E+04	4.97	**0.010* Reject H_o**	0.79
12. Distance to restored habitat (m)	Location	Between Groups	2	8604.74	4302.37	0.87	0.43 Accept H_o	0.19
13. Distance to overflow channel (m)	Location	Between Groups	2	82.77	41.38	0.10	0.91 Accept H_o	0.06
14. Nearest woody vegetation ht (m)	Location	Between Groups	2	88.36	44.18	0.82	0.44 Accept H_o	0.18
15. NWV foliage rad. (m)	Location	Between Groups	2	7.99	3.99	1.02	0.37 Accept H_o	0.22

16. NWV ht.(m)	Location	Between Groups	2	48.93	24.46	4.41	**0.016* Reject H_o**	0.74
17. Nearest woody vegetation dbh (cm)	Location	Between Groups	2	89.95	44.98	4.15	**0.020* Reject H_o**	0.71
18. % tree cover	Location	Between Groups	2	907.17	453.59	0.66	0.52 Accept H_o	0.16
19. % grass cover	Location	Between Groups	2	2174.60	1087.30	5.06	**0.009* Reject H_o**	0.80
20. % herb	Location	Between Groups	2	5152.56	2576.28	1.88	0.16 Accept H_o	0.38
21. % shrub	Location	Between Groups	2	1.94E+04	9690.18	7.46	**0.001* Reject H_o**	0.93
22. % bare ground	Location	Between Groups	1	2828.83	1414.42	1.56	0.22 Accept H_o	0.32
23. % cov. dead forb	Location	Between Groups	2	5419.56	2709.78	3.04	0.06 Accept H_o	0.57
24. Nest cover standing/1m	Location	Between Groups	2	1725.31	862.66	1.29	0.28 Accept H_o	0.27
25. Nest cover % above	Location	Between Groups	23.89767	3532.40	1766.20	1.96	0.15 Accept H_o	0.39
26. Low Nest Coverage	Location	Between Groups	2714.622	4322.63	2161.31	2.59	0.08 Accept H_o	0.50

Appendix D – ANOVA of vegetative characteristics with nest success/ unsuccess as dependent variable

H_0 = the observed differences in habitat variables among successful and unsuccessful nests vary by chance alone.

Response Variable	Term	Source of Variation	Df	SS	MS	F-Ratio	Power (Alpha = 0.05)	Prob Level
1. Location	Success (1)/ Failure (0)	Between Groups	1	0.46	0.46	0.71	0.40 Accept H_o	0.13
2. Year	Success (1)/ Failure (0)	Between Groups	1	1.28	1.28	6.16	**0.016* Reject H_o**	0.69
3. Nest Height	Success (1)/ Failure (0)	Between Groups	1	77.43	77.43	0.14	0.71 Accept H_o	0.07
4. Plant Height	Success (1) /Failure (0)	Between Groups	1	6.60	6.60	0.00	0.97 Accept H_o	0.05
5. Micro size (m2)	Success (1)/ Failure (0)	Between Groups	1	1.07E+08	1.07E+08	5.75	**0.019* Reject H_o**	0.66
6. Average ht micro (m)	Success (1)/ Failure (0)	Between Groups	1	2.33	2.33	1.60	0.21 Accept H_o	0.24
7. Dist. to edge of micro (m)	Success (1)/ Failure (0)	Between Groups	1	27.23	27.23	0.56	0.46 Accept H_o	0.11
8. Macro size (m2)	Success (1)/ Failure (0)	Between Groups	1	2.72E+07	2.72E+07	1.46	0.23 Accept H_o	0.22
9. Average ht macro (m)	Success (1)/ Failure (0)	Between Groups	1	5.84	5.84	0.79	0.38 Accept H_o	0.14
10. Dist. to edge of macro (m)	Success (1)/ Failure (0)	Between Groups	1	276.51	276.51	0.76	0.39 Accept H_o	0.14
11. Distance to	Success (1)/	Between	1	1.80E+0	1.80E+0	3.31	0.07	0.43

forest (m)	Failure (0)	Groups		4	4		Accept H_o	
12. Distance to restored habitat (m)	Success (1)/ Failure (0)	Between Groups	1	2743.32	2743.32	0.55	0.46 Accept H_o	0.11
13. Distance to overflow channel (m)	Success (1)/ Failure (0)	Between Groups	1	60.08	60.08	0.15	0.70 Accept H_o	0.07
14. Nearest woody vegetation ht (m)	Success (1)/ Failure (0)	Between Groups	1	37.03	37.03	0.69	0.41 Accept H_o	0.13
15. NWV foliage rad. (m)	Success (1)/ Failure (0)	Between Groups	1	20.27	20.27	5.57	**0.021* Reject H_o**	0.64
16. NWV ht.(m)	Success (1)/ Failure (0)	Between Groups	1	1.83	1.83	0.29	0.59 Accept H_o	0.08
17. Nearest woody vegetation dbh (cm)	Success (1)/ Failure (0)	Between Groups	1	18.37	18.37	1.55	0.22 Accept H_o	0.23
18. % tree cover	Success (1) /Failure (0)	Between Groups	1	68.65	68.65	0.10	0.75 Accept H_o	0.06
19. % grass cover	Success (1) /Failure (0)	Between Groups	1	0.13	0.13	0.00	0.98 Accept H_o	0.05
20. % herb	Success (1) /Failure (0	Between Groups	1	418.92	418.92	0.29	0.59 Accept H_o	0.08
21. % shrub	Success (1) /Failure (0)	Between Groups	1	506.25	506.25	0.32	0.57 Accept H_o	0.09
22. % bare ground	Success (1)/ Failure (0)	Between Groups	1	89.12	89.12	0.10	0.76 Accept H_o	0.06
23. % cov. dead forb	Success (1) /Failure (0)	Between Groups	73.63	2337.74	2337.74	2.52	0.12 Accept H_o	0.35

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24. Nest cover standing/1m	Success (1) /Failure (0)	Between Groups	17	2274.67	2274.67	3.50	0.07 Accept H_o	0.45
25. Nest cover % above	Success (1) /Failure (0)	Between Groups	17	384.91	384.91	0.41	0.52 Accept H_o	0.10
26. Low Nest Coverage	Success (1) /Failure (0)	Between Groups	17	3936.69	3936.69	4.76	**0.033*** **Reject H_o**	0.57